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FUEL — ELECTRICITY — MACHINERY — METHODS

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DECEMBER 1924

Containing the Proceedings of the A.I.&S.E.E.

Gear Drives in the Steel Mills

By H. H. TALBOT

Assistant Chief Engineer, United Engineering & Foundry Company
Pittsburgh, Pa.

Direct Current Hoist and Trolley Control for Ore Bridges

By N. L. MORTENSEN

Design Engineer, Cutler Hammer Manufacturing Company
Milwaukee, Wis.

Electric Industrial Locomotives

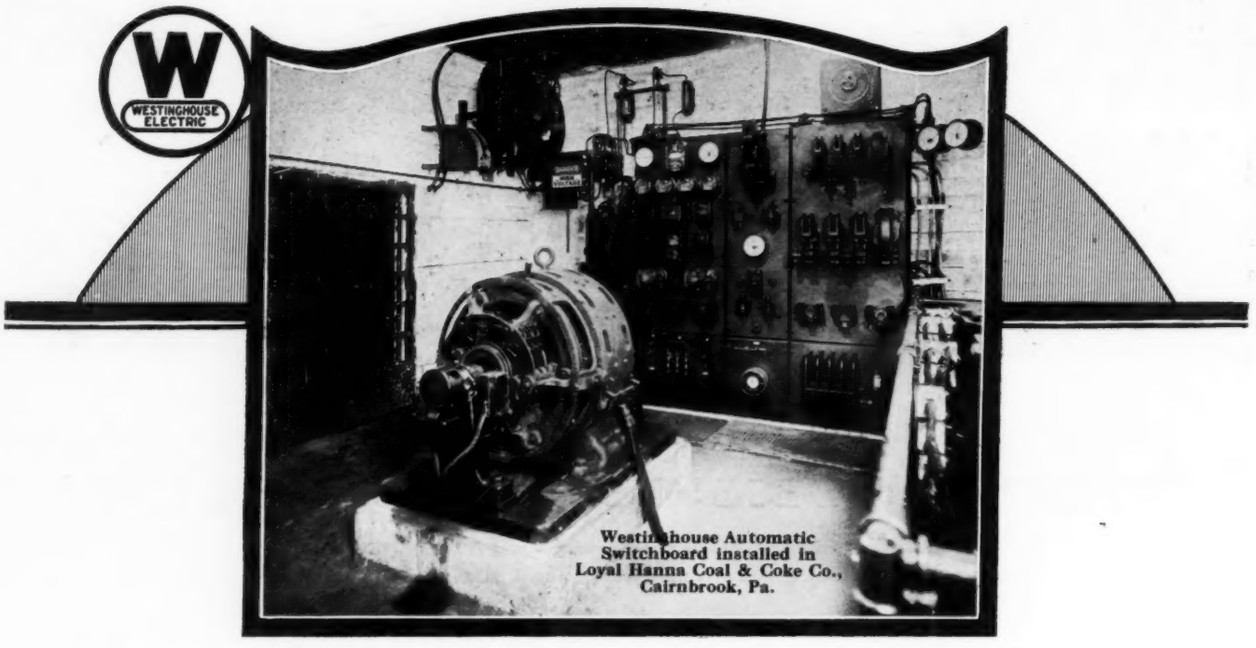
By FRANK E. FISHER

Engineer, Goodman Manufacturing Company
Chicago, Ill.

Breaking Spindles for Main Roll Drives

By J. H. ALBRECHT

Engineer, Thomas Flexible Coupling Company
Pittsburgh, Pa.



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IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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MEETINGS and PAPERS

PHILADELPHIA SECTION

P. T. Vanderwaart, Chairman **L. O. Morrow, Secretary**

Saturday, January 3rd, 1925

"Relation Between Technical Papers and the Life and Work of the A. I. & S. E. E.," by A. J. Standing, Superintendent Electrical Department, Bethlehem Steel Company, Saucon Plant, Bethlehem, Pa.; A. C. Cummins, Electrical Superintendent, Carnegie Steel Company, Duquesne, Pa., and John F. Kelly, Business Manager, A. I. & S. E. E., Pittsburgh, Pa.

Engineers Club **Philadelphia, Pa.**

CHICAGO SECTION

R. L. McIntosh, Chairman **W. H. Williams, Secretary**

Monday, January 26th, 1925

"Joint Meeting With Chicago Section of American Institute of Electrical Engineers and Electrical Section Western Society of Engineers."

"Automatic Substations in Steel Plants," by G. P. Wilson, Engineer, Steel Mill Section, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

Atlantic Hotel **Chicago, Ill.**

CLEVELAND SECTION

A. W. Mohrman, Chairman **A. R. Lintern, Secretary**

Monday, January 12th, 1925

"Steel Treating and Its Value to the Steel Industry," by R. F. Crump, Engineer, Stroh Steel Hardening Process Company, Pittsburgh, Pa.

Electric League Rooms, Statler Hotel **Cleveland, Ohio.**

PITTSBURGH SECTION

R. E. Lewis, Chairman **John F. Kelly, Secretary**

January, 1925

Inspection Trip

"A Modern Sheet Mill Plant, Youngstown Sheet & Tube Company."
Meeting will be held in Youngstown, Ohio. Details later.

BIRMINGHAM SECTION

F. G. Cutler, Chairman **W. W. Garrett, Secretary**

W. H. Dunn
A. F. Elliott

Executive Committee

W. H. Gilbert
W. B. Connally

To All Our Friends

I know our membership joins me in expressing the appreciation and thanks which are due you for the successful achievements of this Society during the past year.

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Yours very sincerely,

ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS

R. S. Shoemaker,

President

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Gear Drives in the Sheet Mills

By H. H. TALBOT*

IN thinking of this subject, the mind naturally turns to the little brother of the main gear drive, the set of gears commonly known as the "pinion stand" which directly drives the rolls of the roll stand or mill. This unit is an essential part of the mill drive and, like the needy, "always has been and always will be with us."

The early forms of pinion stand very closely resembled a stand of rolls, consisting of two housings

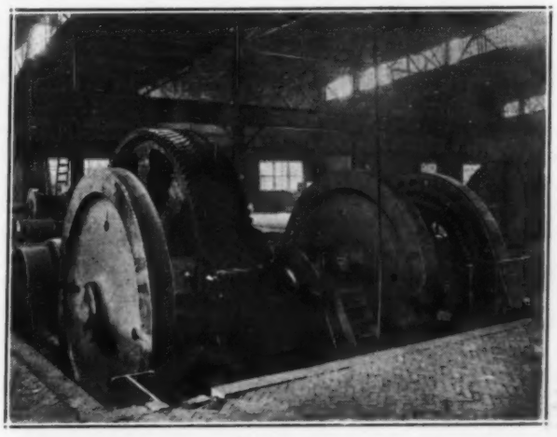


FIG. 1.

containing bearings and carrying two or three meshing pinions assembled in the same manner of arrangement as the rolls of the roll stand. As the roll stand is known as "two high" or "three high" the pinion stand is likewise designated according to the number of pinions it contains.

In this early type of stand, the gears or pinions had cast spur or straight teeth, and were not enclosed or protected. A heavy tar compound smeared over the teeth formed the lubricant.

On account of the small number of teeth in these spur pinions, hardly more than a pair of teeth were in contact at a time, resulting in a varying angular velocity, tooth shock and other ills, such as fluctuating surface velocity of the mill rolls.

Conditions were improved somewhat by the use of cut spur teeth which gave more uniform tooth contact and permitted the use of forged steel pinions. Later the double helical or herringbone toothed pinion was developed. It was necessary to cast these teeth as no cutter had as yet been devised to cut them. The theory of the advantage of cast teeth, due to the reputed hard surface of the teeth, seems to have gained firm foot hold in the minds of mill operators and even to this day, when cutting of double helical teeth has been developed to a nicety, one frequently finds it necessary to argue this point.

The inherent properties of the double helical tooth such as uniform angular velocity, elimination of tooth shock, and resulting greater strength and life, gained for this type of gear a lasting popularity. These properties, markedly apparent in the cast tooth gearing, were still further emphasized when it became possible to cut double helical teeth, and on account of this superiority practically all modern pinion stands are equipped with either cast steel or forged steel pinions having cut teeth of this type.

(Parenthetically, it might not be amiss to state that it is the writer's understanding that the first machines developed in his country for cutting double helical toothed gearing were designed, built and installed in the plant of the William Tod Company of Youngstown, Ohio—along in 1912-1913. These machines cut by the planing process.)

Apace with the development and refinement of the gears themselves, it became necessary, from a protective standpoint as well as to keep in line with the general demands for refinement and economies in operation, to improve the method of housing and lubricating the pinions. We, therefore, find steps in the evolution of the housing starting with the completely open type where the pinions are entirely exposed or semi-enclosed by means of boards or steel covers, largely effective only in catching the grease thrown off the teeth and as a safety protective feature; then follows the fully enclosed, oil tight and dust proof housing of the modern design.

One type of the fully enclosed housing permits the use of the same oil on the bearings and teeth and is known as the single oiling system. For this system of oiling it is necessary to compromise as to the grade

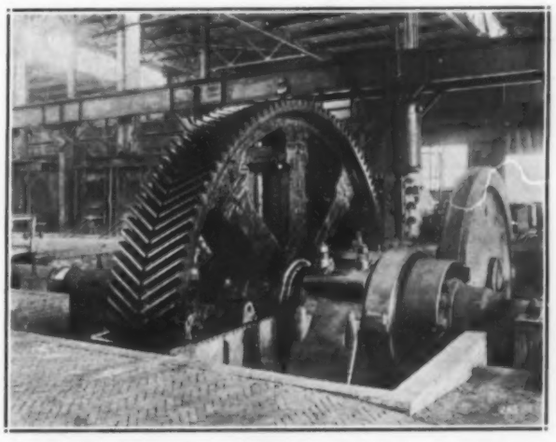


FIG. 2.

of oil, between the demands of the bearings and the teeth, using an oil of as high a viscosity as will flow through the bearings for the sake of the advantage of high viscosity oil on the pinion teeth. The pitch velocity of the pinion is comparatively low resulting, for the power transmitted, in fairly high tooth pressure. Except for the elasticity of the metal of the tooth surfaces, the contact between the teeth is theoretically that of line contact. It is evident then that the maintenance of an oil film between the tooth surfaces is an essential though difficult matter. Breaking

*Assistant Chief Engineer, United Engineering & Foundry Company, Pittsburgh, Pa.

down of this oil film, allowing metal to metal contact, will soon result in tooth wear. An oil of sufficiently high viscosity to maintain this oil film is a necessity.

In the majority of merchant mills where the pitch velocity is comparatively high and conversely the tooth pressure is comparatively low, an oil of about 600

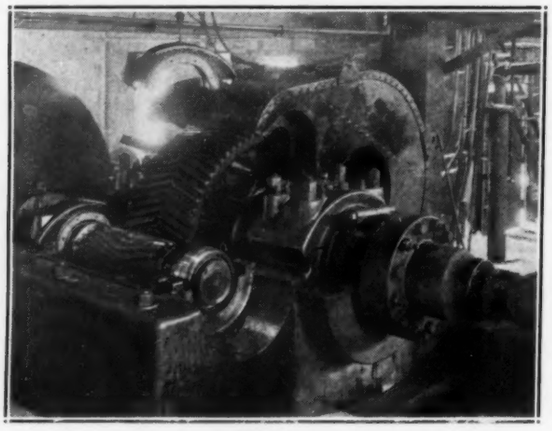


FIG. 3.

viscosity gives very satisfactory results on both bearings and teeth.

In the usual construction of pinion housings, the bearings consist of separate babbitted shells and as the outside radius of the pinion is only a trifle larger than the distance from the centerline of the bottom pinion to the seat or joint of the bottom shell in the housing, it is impossible to have the teeth dip in a bath of oil. The oil level in the gear case required for dipping of the teeth would come above the shell seat resulting in leakage of oil to the outside. The gear case then is used for a drain reservoir only, the oil being spilled on the teeth from above, through the housing cap. The oil supplied to the bearings also drains into this case.

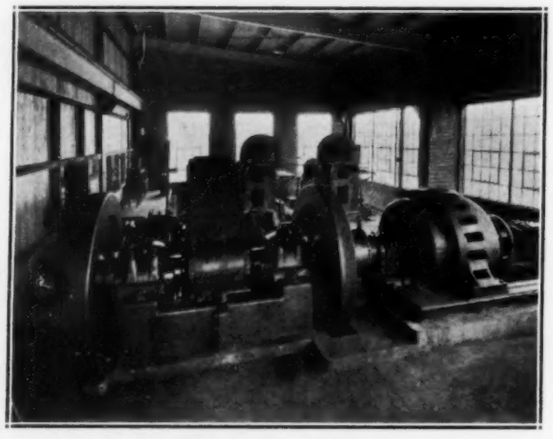


FIG. 4.

If the pinion stand has a unit oiling system, the oil is taken from this reservoir by a rotary pump, or other means and passing through a filter is distrbuted through sight feeds to the bearings and gears, forming a circulating system. If a central oiling system is used, the oil is drained to the central filters, raised to a central overhead tank and distributed to the several units.

For the heavy duty pinion stands, where the high tooth pressures prevail, such as for blooming mills, plate mills, billet mills, etc., a lubricant of such a high viscosity is required for the teeth that it is impossible to use the same for lubricating the bearings. This condition calls for double oiling system or use of a separate lubricant on bearings and on gears. The bearings are usually supplied and drained separately with a light oil after the manner described for the single oiling system.

Heavy gear grease or shield is swabbed at intervals on the gear teeth through the inspection doors of the gear case or, warmed to a flowing consistency in an outside supply reservoir by means of steam coils, is fed to the pinions by pipes through the housing cap, a pump or other pressure means being used to force the lubricant to circulate.

In this double oiling system it is necessary that the bearing shells be equipped with grooving and wipers constituting a means of preventing an interchange or mixing of the two lubricants. A thinning of the gear lubricant by the bearing oil soon lowers its viscosity and renders it inadequate for tooth lubrication, while

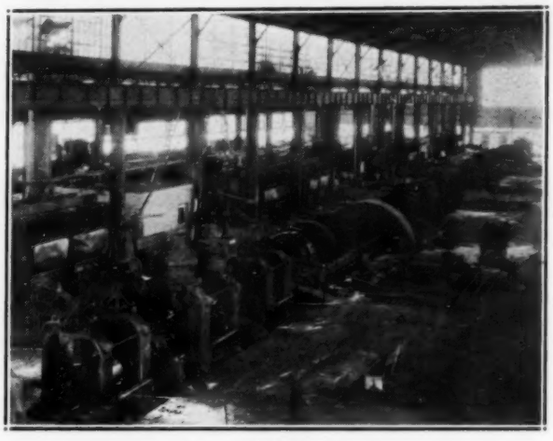


FIG. 5.

a working in of the gear grease into the bearings soon prevents proper circulation of bearing oil, thickens same and causes bearings to heat.

Passing now to the main units utilized for driving these pinion stands, we find a variety of types.

The early mills were driven largely by steam engines either direct connected or through belt or rope drives or sometimes through gear reduction sets. All of these types will still be seen in service and the steam reversing engine direct connected to blooming mills is considered by some to be good present-day practice. Perhaps the most recent installation of this kind (built by the United Engineering & Foundry Company), is that at the Weirton Steel Company for driving their reversing blooming mill consisting of 42 in. x 60 in. x 66 in. Twin Tandem Compound engine.

Some sheet mills and Belgian mills are still driven by multiple rope drives and some small merchant mills by belt drives.

The speeds available with the steam engine were practically that required for the mills so that a reduction gear unit was seldom found necessary. The development of the electric motor of sufficient stamina

to withstand the requirements of rolling mill service has practically entirely supplanted the steam engine as a local driving unit. The speeds of such motors, except for a few expensive slow speed types, are considerably higher than the speed of the mills and though the rope drive has been used in some installations for nominal speed ratio, the real answer to the speed reduction problem has been the gear drive.

If we trace through the development of the gear drive, we find that it has passed through much the same process of evolution as has the "pinion stand", above outlined, until we have the example of the refined design and operating efficiency of the modern unit. The various parts of the drive have been improved and refined through successive designs and it may be interesting to note briefly, some of these steps of progress.

The design of the bearings as to essentials had a fairly good start due to previous experience with engine bearings. Some of the early types were even made with quarter boxes in accordance with engine practice. This was soon found to be an unnecessary feature, the solid split shell type being superior. Refining features were soon added, such as oil catching wells, oil throwers and various designs of wipers, packing, etc., for making the bearings dust proof, for returning the oil to filters and preventing mixture of bearing and gear lubricants. The high surface speeds and high bearing pressures of the pinion shaft bearings, especially encountered when flywheels are carried on the shaft, require very careful attention to be given to the proper proportioning of the journals and to insure effective lubrication. The modern bearings consist of babbitted bottom half shells resting in the bored seats of the bed, and either babbitted cap or top half shells.

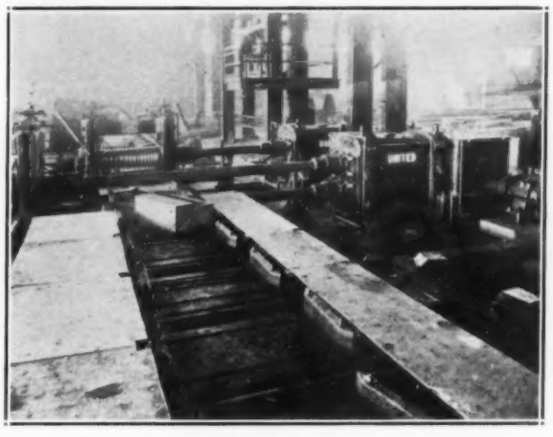


FIG. 6.

Gravity or pressure sight feed, chain or oil ring systems of lubrication are all used, the choice depending on the bearing conditions as to pressures, speed, etc.

In the earliest drives the "bed plate" consisted merely of four separate pillow blocks, containing the bearing and supported individually on the foundation. Later the main bearing pillow blocks were extended under and supported the pinion bearing pillow blocks, forming a double bearing frame or separate bed plate either side of the gears. Then the pinion bearing block was eliminated and the bearings were supported immediately in these side frames. The latter was a great improvement but all of these arrangements are dependent on the foundation for alignment of bearings and gears and require very careful setting up.

The Apollo Sheet Mill drive is an example of this double side frame type, which drive built in 1912-1913 is still in successful operation.

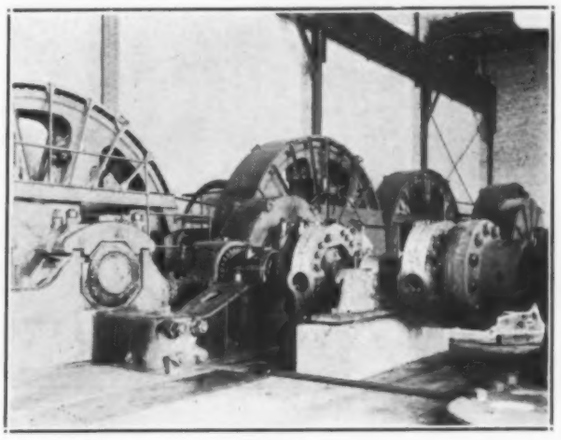


FIG. 7.

The continuous bed plate completely encircling the gears and forming a one-piece frame under all bearings was the next development and constitutes the modern design. The main bearings are seated immediately in this frame. In some modern designs the pinion bearings have separate pillow blocks supported on this bed between keeper lugs, and bolted thereto but the preferred design has the pinion bearings also immediately supported in the bed.

The gear covers have progressed from none whatever, to railings around the pit—sheet steel over the gear face only—to the modern fully enclosed oil tight and dust proof type consisting of cast iron or steel plate top cover and bottom pan.

FIG. 8.

The gears have passed through much the same stages as outlined for the pinion stands, namely, cast steel shrouded spur tooth pinions and gears; cast or forged steel cut spur pinion and cut cast steel spur gears; cast tooth double helical pinions and gears; to the cut double helical forged steel pinions and cut cast steel gears of the modern drive.

A variety of designs for the main gears themselves are in vogue at present among the various builders. These in brief involve the following features. One piece casting having solid hub and "H" or double channel section spokes; split hub held by shrink links or rings; separate tooth rim shrunk over a spider or

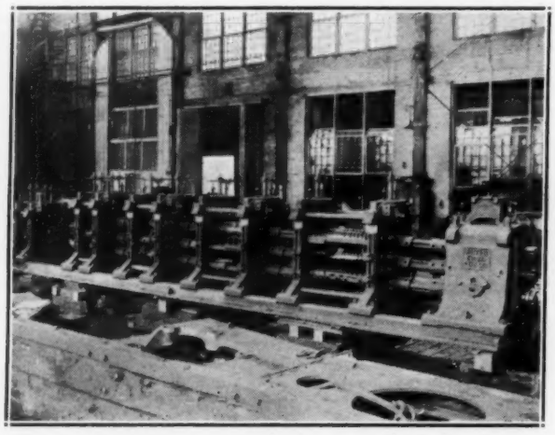


FIG. 9.

blank; one piece casting having tooth rim, hub and vertical web; one piece casting having rim, hub and umbrella shaped web.

The very large gears, say 16 to 20 feet in diameter, are usually made in halves on account of shipping limitations. Such gears have one of the above spoken constructions, the halves being held together by combination of bolts, shrink links and rings.

Dependent on the reduction ratio required and the pitch diameter involved, the pinion is preferably made of forged steel integral with the shaft and usually of .50 to .60 per cent carbon steel.

The cast steel gear usually runs from .30 to .40 per cent carbon.

While all very interesting to the designer an adequate presentation of the subject of tooth forms and action would involve too long a discussion to find a

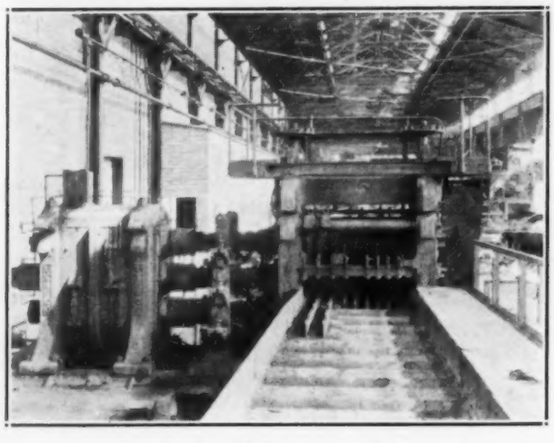


FIG. 10.

welcome place in this paper. It will perhaps suffice to say that almost every form of tooth has been used, both cycloidal and involute with varying involute angles, longer than standard teeth in the early cast tooth gears, standard length, stubbed tooth length, and long and short addendum stub.

For cut toothed gearing, it has been general practice to use the stub tooth in which the addendum (height above the pitch line) equals $\frac{.8}{\text{diameter pitch}}$ and addendum (depth pitch line to root) equals $\frac{1}{\text{diameter pitch}}$ the total height being $\frac{1.8}{\text{diameter pitch}}$. This is a shorter and stronger toth than the ordinary standard.

In the long and short addendum type the addendum on the pinion is made, for example, $\frac{1}{dp}$ and the dedendum $\frac{.8}{dp}$ and for the gear the addendum is $\frac{.6}{dp}$ and the addendum $\frac{1.2}{dp}$. Measured on their respective pitch lines, the thickness of tooth of the gear is thinner than the pinion tooth, approximating for most ratios 45 per cent and 55 per cent respectively of the circular pitch, so that if the profiles of the pinion and gear teeth are superimposed regardless of pitch lines,

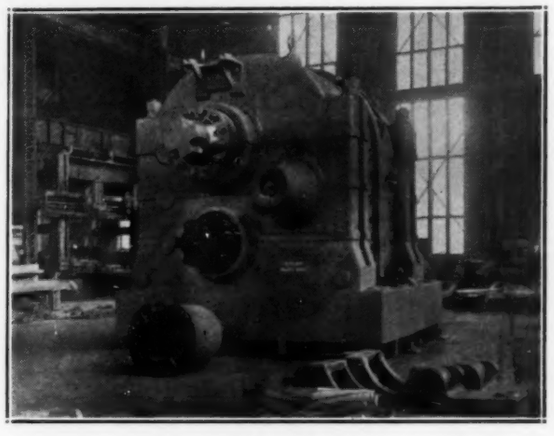


FIG. 11.

they form tooth sections of practically the same shape and strength proportions.

The short addendum of the pinion avoids the radial undercut of the involute usually aparent in pinions of less than 16 or 18 teeth and thus gives a much stronger tooth.

Gears of this type run much more quietly than the standard or the stub tooth gears due to the smaller arc of approach and relatively greater arc of recess, making up the full arc of tooth action.

The pinions of the ordinary pinion housing are usually made symmetrical so that they can be interchanged, thereby limiting the number of spares to be kept in stock. For this reason, the stub tooth form will continue to prevail for these pinions.

Due to the machining limitation of some gear cutters a helical angle of 23 deg. has been used extensively. A steeper angle has advantages and a 30 deg. angle is to be preferred. Most of the European gears have a 45 deg. angle and it will be interesting to note whether American practice will in the future approach this angle.

We have the same system of oiling in the gear drives as outlined for the pinion housings, namely,

"single" or "double". Due to the depth of gear case, the oil bath can be readily used alone, or in addition to streams of oil delivered directly on the teeth. Since the pitch velocities are comparatively high (1,600 to 3,000 ft. per minute) with correspondingly lower tooth pressures, it is possible to use the single oiling system for much greater horsepowers transmitted than in the pinion housings.

Drives embodying any number of combinations of the above features of construction will be found in operation.

Gear reduction units may be in general classified under two headings, namely:

Drives transmitting no flywheel power.
Drives which do transmit flywheel power.

The former can be called upon only to withstand the maximum overload capacity of the motor with perhaps the additional flywheel effect of the motor rotor, should the mill become jammed, while the latter in addition to the above must withstand the power delivered by the flywheels.

As far as the drive is concerned, the ideal location for the flywheel is in connection with the main shaft

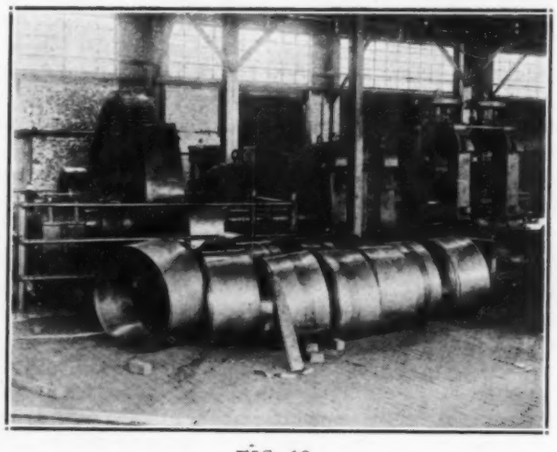


FIG. 12.

and between the mill and the drive. The flywheel then protects the drive against shock and the drive is required to transmit the motor load only. The usual low sped of the main shaft, for the aomunt of the flywheel effect generally required, necessitates a very large and expensive flywheel, and though more modest proportions of the gear drive are possible under these conditions, it usually works out to be the more economical construction to locate the flywheel in connection to the pinion or high speed shaft.

A single flywheel mounted on separate hearings and located between the motor and drive pinion, is the original arrangement for the high speed flywheel. The second method was first proposed and used by the United Engineering & Foundry Company as applied to a steel mill drive, in the face of considerable criticisms and "it can't be dones" in the construction of the 1,500 hp. sheet mill drive built for the Apollo Steel Company along in 1912. This arrangement consisted in mounting a cast steel 13 ft. 3 in. diameter flywheel weighing 40,000 lbs. on each end of the pinion shaft overhanging the pinion bearings, the motor running at 237 rpm. The motor pinion is 30 in. PD., ½ D.P., 42 in. face and the gear is 232 in. PD., ½D.P., 42 in. face which runs the mill at 30.6 rpm. This construction worked out very satisfactorily and is used in practically all the more recent flywheel drives.

A flywheel revolving at a given speed, as we all know, has a given amount of foot pounds of energy

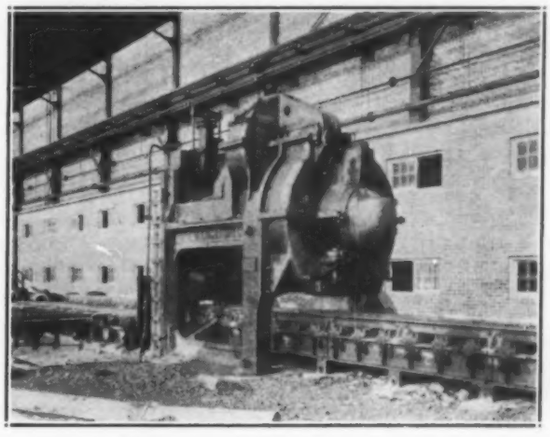


FIG. 13.

stored therein, $E = \frac{WR^2 N^2}{5870}$. It will deliver energy only on condition that some load opposes its rotation causing a reduction in speed. The amount of energy given up is the difference in the initial total and the remaining energy corresponding to the final speed, or equals $\frac{WR^2 (N_1^2 - N_2^2)}{5870}$, where N_1 = initial rpm. and N_2 = final rpm. Dividing by 550, we have this energy expressed in terms of hp. seconds.

In designing gears interposed between the flywheels and the mill, it is necessary to make some reasonable assumption as to the drop in speed that is likely to take place in an assumed space of time due to some likely or possible overload condition transmitted to the main shaft.

FIG. 14.

The drop in speed determines the amount of energy given up by the flywheels and the interval of time in which this delivery occurs, determines the rate of work delivered, or the average hp. to which the gears are subjected during this interval.

Assuming a normal sheet mill drive driven by a 1,000 hp. motor, the usual flywheel effect, at 20 hp. seconds per hp., would be 20,000 hp. seconds. Assuming a speed drop of 20 per cent in one second, the average hp. delivered by the flywheels would be in proportion to the difference of the squares of the initial and final rpm., (or expressed in percentages $N_1 = 100$ per cent and $N_2 = 80$ per cent), and would equal $0.36 \times 20{,}000 = 7{,}200$ hp. With 200 per cent load on motor = 2,000 hp., we would have a total of 9,200 hp. average, transmitted through the gears. Should we assume the drive actually stopped in one second, we would have a total average hp. transmitted during this second of 20,000 plus 2,000 or 22,000 hp.

The gearing should be designed for running conditions under a load causing a speed drop normally anticipated due to conditions of rolling, and for strength in reference to assumed possible loading, after the manner above outlined, which may be reasonably expected due to a jamming of the mill or other causes. The breaking torque of the loading spindle would form another check for strength.

FIG. 15.

Another important analysis in a drive of this kind has reference to the conditions of deflections in the pinion shaft.

Supported on two bearings, we have a flywheel weight load on each end outside the bearings, and if the pinion rotates "under" a tooth load downward on the center. This tooth load tends to straighten out the shaft, balancing the flywheels, but causes the bearings to carry total weight plus the tooth pressure. If the pinion rotates "over" or "climbs" the gear, this central tooth pressure is up relieving the bearing load but augmenting the upward deflection or bowing of the shaft.

We have burdened you with these features essential to proper design, with the idea that, although as steel mill electrical engineers, you may not be called upon to actually design a drive, these points may assist you in an analysis of drives proposed for your recommendations. As in the automobile world, there are Fords and Packards all proposed to transport five passengers, so in drives there are light designs pruned to the limit for the service required and more liberal designs, giving longer life and less interrupted service.

Classifying under the subject of this paper, we find other types of drives which we will only hurriedly mention, as follows:

The double reduction drive frequently substituted for the single reduction units, where the reduction ratio is large, avoiding the very large main gear.

Gear trains, used frequently for driving continuous mills, each gear driving alternately top and bottom pinions of the pinion stands, or with idlers interposed so that the driving gears lying on the same horizontal centerline, are connected to the bottom pinions.

Spur or single helical toothed gearing is preferable for such trains since with the most accurately cut double helical gears, there is always some tendency for the gears to float due to a very slight wavering of the line of apeci of the teeth about an exact centerline of the gear face. This tendency is multiplied through successive gears and although a possible, it is a mechanically difficult arrangement.

Bevel gear drives are also used very generally for Continuous Mills. A line shaft carrying a series of varying diameter gear drives through mating bevel gears, the cross shafts immediately connected to the pinion stands of the successive roll stands. The line shaft is usually driven by a single reduction unit or sometimes directly by a slow speed motor.

The drives used on the modern motor driven shears will also classify as real gear drives and among the less prominent, though important drives, may be cited those used for roller tables.

Exemplifying some of the drives and features mentioned in this paper, possibly the lantern slides which have been prepared will be of interest, and with your permission—we will proceed to show them on the screen.

DISCUSSION

Fred Schnure*: Mr. Chairman, Gentlemen: It seems the present practice in main roll drive is to use high speed motors with reduction gear units, in preference to the rather old practice of large slow speed motors. This has been made possible because of the improvement in gear design. This gentleman, representing the United Enginering Company, has evidently done his share toward this betterment and the practice seems to be altogether successful. We have at Sparrows Point at the present time, 11 gear reduction units, ranging from 500 to 3,000 hp., and all things considered, they seem to work right well. We have had three 1,000 hp. units working since 1917 and about six others of the same size working since 1920 on tin and sheet mill service, and two 3,000 hp. units were just put into service on Wednesday of this week on rail mill service. There will be three more 1,000 hp. units installed sometime between now and spring, making a total of 14 for our plant.

The only trouble we have run into on the thousand hp. drives, has been due to some wear on the pinion bearings.

This is due I believe, to the fact that at the start we didn't have an adequate oiling system. I believe that gear manufacturers and plant engineers when installing such drives should make it a point to see that a first class oiling system is a part of the unit.

On the latest units — the rail mill units — we have a system consisting of filter, storage tank with gravity feed, all automatically operated. The lubrication of the gear units is taken care of by two distinct sys-

*Superintendent Electrical Department, Bethlehem Steel Company, Sparrows Point, Md.

tems, the gravity system feeding the bearings and the splash system lubricating the gears themselves.

This rail mill drive went into operation very nicely, one unit on the roughing stand and the other on the finishing and intermediate stands. The intermediate started off without any trouble at all. On the roughing drive — one flywheel opened up a trifle — some stress — likely due to speed — and caused a little unbalancing, which was not hard to clear up with a few weights.

In the short time we have been operating, the mill people feel that the gear drive is an improvement over the engine drive. This may be partly due to a more steady torque exerted by the motor, or it may be helped along a little by the fact that we have installed cut mill pinions at the same time instead of the old cast pinions.

The flywheels on this outfit have about 40,000 hp. second capacity.

W. H. Burr*: Chairman and gentlemen, I feel that to a large extent the improvement in the design in reduction gears has been the result of the gradual change from 25 cycles to 60 cycles in our power systems. This change in frequency was made possible by the improvement in design of 60 cycle rotary converters. Slow speed 60 cycle motors are expensive and when used in connection with mill drives cause trouble due to low power factor. It was then necessary to find some way to operate 60 cycle motors under good power factor conditions and still get low speed necessary on mill drives. The reduction gear is now doing this in a very satisfactory manner. The author of the paper presented tonight has covered this subject very carefully and very thoroughly.

A number of questions which came to my mind during the presentation of the paper were answered by the speaker when showing the slides. There are, however, a few points on which I would like more information. I notice that on all of the gears shown in the slides this evening, the tooth is a double helical tooth, but the tooth is not continuous. I would like to ask Mr. Kline what percentage of increase in strength would be obtained if the tooth were made continuous instead of being designed with clearance circle in the center of the gear. I recall one installation of the Kennedy pinion housing on which trouble was encountered with the teeth of the pinion that an attempt was made to build up the tooth by electric welding. I would like to ask the speaker if he has any knowledge of or considers it good practice to build up teeth in reduction gears by electric welding.

The question of flexible couplings, while not a part of this paper, enters into the construction of reduction gear outfits and I was in hopes that the author of the paper would give us a little more information on that subject this evening. I would like to ask if from a builder's standpoint they would prefer to specify the coupling used rather than have this specified by the purchaser.

The question of oiling is one that the speaker feels cannot be overlooked. If this is the case it would seem that suitable means of taking care of the filtering of the oil should be provided when an expensive installation is being contemplated.

*Superintendent Electrical Department, Lukens Steel Company, Coatesville, Pa.

The question which was brought up during the presentation of the paper, of the direction of rotation of the pinion so that the thrust is thrown on the caps of the bearings, is one that should be given careful consideration. If the fly wheel is of considerable there is an advantage in operating it so that this weight is removed from the bearings of the reduction gear outfit.

A great amount of credit is due Mr. Talbot and Mr. Kline and I feel we owe them a vote of thanks for the paper presented this evening.

C. J. Klein*: I might make a remark or two. I think Mr. Schnure is perfectly right. Most of the trouble with drive units, say 95 per cent of the trouble, is due to the oiling arrangement — getting the proper lubricants in the bearings and on each of the gears. I think the other 5 per cent is due to misalignment, deflection in the shaft, couplings, etc. But the lubrication system is the main thing in the drive.

I might mention in connection with the fly wheels that we find it more advantageous to make a solid plate fly wheel where the speeds run high, say up to 18,000 feet a minute peripheral speed. Solid plate fly wheels are cut from rolled plates four to six inches in thickness and up to 12 feet in diameter, being about the maximum. This will eliminate the opening up condition. Of course we all know a cast steel fly wheel will not run as high as 18,000 feet a minute, their limit being about 12,000 ft. per min.

In answer to Mr. Burr's question as to what percentage increase is gained in the strength of gears having no clearance circle cut in the center over the gears having a circle.

I believe it would increase the strength very little and in addition will not give a tooth with uniform strength for this reason: Ordinarily on a cast tooth gear the teeth were reinforced on the ends with a shroud as well as being tied in the center this design giving a tooth practically uniform in strength. In other words the tooth is stronger in the center than at the ends and does not give you the best design.

The usual protection in case the mill should stall is the breaking of the leading spindle or coupling box, these parts being designed strong enough for ordinary work. All other parts are designed considerably stronger. In answer to the question as to building up gear teeth. This procedure has been reverted to time and again and it works out very satisfactorily. The building up of wabbler ends on rolls, pinions, and spindles is also done extensively.

The question of flexible couplings: While there are a number of types of flexible coupling on the market at the present time, not more than four or five are used on rolling mill machinery drives, etc. The United Foundry & Engineering Company do not specify any particular type of coupling. We furnish whatever type the customer prefers unless he says he wants a coupling and leaves it up to us; we will then specify a particular type which is satisfactory for the service, as we have had a great deal of experience with couplings in connection with drives.

The question of oiling is usually taken care of by the mill men themselves for the simple reason that they have had considerable more experience with local

*Engineer, United Engineering & Foundry Company, Pittsburgh, Pa.

conditions. In other words as far as my experience goes there are no two systems that will work out exactly alike.

Oiling systems are not usually furnished with drives because the customer has a central system which can be connected very readily. These systems have filtering screens, etc., and are taken care of more economically than individual systems.

But as some of the slides showed we do install individual systems on some machinery.

The question as to bearing pressure on motion pinion caps.

There are conditions where it is necessary to run the pinion "over" as when heavy fly wheels are mounted on the shaft, thereby relieving the bearing pressure on the bearing. There are certain limits to the amount of bearing pressure and velocity combined, which a particular type of lubrication can stand. In other words ring or chain oil bearings cannot stand the loads that force feed can, then again there are conditions which require the cooling of the oil and also water cooled bearings but when these are exceeded it is necessary to relieve the loads and run the pinion "over". Very often in running the pinion "over" the load of the fly wheels exceeds the tooth load for normal running and therefore the shaft does not lift.

J. C. Reed*: I noticed in the pictures this evening that practically all the views of the fly wheel were of cast steel. Mr. Kline told us they had to make some of them out of plates. That recalls an accident we had at Steelton a few years ago. We put in a cast steel fly wheel on a 1,200 hp. motor. I think the wheel was about 8 ft. in diameter. But the first time we started up the mill before the motor got up to speed the wheel left us. One piece went up the river and one piece went down the river and one piece went up in the air. The piece that went up the river hit a crane overhead and finished that crane. It smashed the bridge motor. So we shoveled that up. And it bent the girders, so you know how much good that crane was. The piece that went down the river went through the 28 in. mill and smashed our traveling tables. The piece that went skywards went up and busted things up. We had a lively time around there and were pushed to get that mill going. So I was just wondering whether you give these cast steel fly wheels any centrifugal tests like we do the guns.

When we build guns we take them out in the wilderness and see which end of the charge is going to fly. So I would like to know if that is done with your fly wheels.

To come back to the point of the gears someone told me it is a paying proposition to use a helical gear on auxiliary motor drives. I haven't got much encouragement. But Mr. Cummins, at the Duquesne plant, has used herringbone gears for auxiliary drives. He contended — and was able to show a great deal of data he had collected that it was a paying proposition to use them but I never learned of anybody else substantiating the results he obtained. The contention he made was that the use of the double helical gear was much smoother and removed the vibration from the motor. As a result they had less commutator trouble and less trouble from faults of the motor due to vibration and in his armature.

Now all these people get gears but I never heard of one being worn out. I never heard of anyone confessing that they wear out. Now I don't know how much more they cost than the spur gears. But they wear out rapidly enough. So it seems to me if it is good medicine for large gears—it seems it might be worth while to take a little dose on the small gears. I would like to hear something on that to know if it would pay to do that. If a spur gear is going to wear out—and even a steel gear will wear out—and if these gears will last twice as long we can well afford to pay twice as much for them, because you not only have the trouble of changing gears—and that costs something—and if they are going to reduce electric trouble you have got that side to consider. So I would like to learn what your engineers think about that.

C. J. Klein: The majority of the drives built by United are tested in the shops before they are shipped. The fly wheels (two being usually mounted on the pinion shaft), are balanced individually and then after mounting are balanced collectively to insure perfect operation of the drives. The fly wheel in question probably had some casting flaws which were not visible, which is another good reason for the perfecting of the X-ray to find these flaws in advance.

Regarding the use of helical gears on auxiliary drives for motors say up to 100 hp.

In the first place the reason spur gears wear out faster than helical gears, is on account of the lack of lubrication. Your spur gears have an open case—no bottom in it. Take that in comparison with your double helical gear drives which are entirely enclosed and run in oil or have a stream of oil running on the tooth. I think the difference would be two to one in favor of the helical gear. In other words the treatment is 100 per cent better than your auxiliary spur drives.

In addition to that it is going to cost you considerably more to put your helical gears in. Not only the cutting of the gear but the oil tight cases which are necessary to preserve your helical gears.

The question of vibration back into your motor can be explained in one way. Ordinarily the spur gear is on the armature. If you place the spur gear between two bearings and put a flexible coupler between the pinion and the motor you would overcome to a great extent the vibartion in the motor because that is one of the reasons for your flexible coupling and that would help your motor to a great extent.

Taking the thing as a whole, and considering the fact that the price of machinery has been increasing in recent years due to too much refinement, it is a question in my mind whether it would be advisable to install double helical cut gears on ordinary drives like tables, transfers, pushers, etc.

We use double helical cut gears on our cold strip mills the hp. of the motor being as low as 75. But as you noticed in that picture it was entirely closed and fed with a stream of oil.

Single helical gears would work out to better advantage than the double helical on small drives due to

*Supterintendent Electrical Department, Bethlehem Steel Company, Steelton, Pa.

the fact that they can be lined up easier, but they should also run in oil.

H. S. Boone*: I was rather impressed with the large amount of hp. seconds delivered in one case by the fly wheels. I would like to know what factor of safety is allowed in the teeth of such a drive. There was a double reduction gear shown on the pictures that had two pinions on the motor shaft. How are the teeth in those pinions, in line or staggered?

In answer to Mr. Reed's question about the helical angle, you said it was the foreign practice to increase the angle to 30 deg. Would not this increased angle make the end thrust excessive?

In the ordinary helical gear is it possible to put the gear on the motor shaft?

Do you think that would apply to motors under 10 hp.?

C. J. Klein: In answer to the question as to the factor of safety allowed in gear drives.

The mill or machine which is being driven usually determines the factor of safety allowed in a gear drive, as the drives are designed to be the last thing to break in case of an accident. The wider the face of the gear and the greater the bearing area of the bearings the longer the drive will last. United drives are designed for long service as well as maximum peak loads.

The pinion teeth shown in the picture are not staggered, in other words they form an ordinary double helical gear. This type of drive, that is, the double reduction with the motor pinion and gear mounted on the outsides of the main gear, is very difficult to assemble but makes the very best design possible.

The tendency to increase the helix angle applies only to double helical gears. Single helical gears usually have a helix angle of about 7½ deg. in order not to produce too great a side thrust.

It is not the practice to place large drive gears on the motor extension shafts as the gear face is rather wide and would cause too much bending in the motor shaft. A flexible coupling is interposed between the motor and pinion. There are some cases where the leading spindles are used between the motor and drives, or mills where the motor is direct connected. The motor builders do not prefer the later design.

Straight spur pinions are mounted on motor extension shafts of motors up to 100 hp. in nearly all cases as the face of the pinion is comparatively narrow—thereby causing little bending. This design is very much cheaper than adding two bearings and a flexible coupling.

G. P. Mills†: I would like to ask the speaker one question. Is it the practice to heat treat the pinions—the cast pinions or the forged pinions on these helical drives?

C. J. Klein: It is not the common practice to heat treat pinions, on account of the cost, and it is only done where it is necessary, such as a condition where the width of pinion face is limited. As the width of the pinion face is usually determined by the permissable bearing pressure on the teeth the question of the strength of the gear does not enter into the calculation.

The heat treating of gears is more expensive than that of pinions and is limited to comparatively small gears.

W. H. Burr: There was one question John Reed brought up about the life of the gears. I had occasion to check up with the gear manufacturers and I found that in one case one gear manufacturer said he had a set of reduction gears to wear out in four years. The general opinion of all the manufacturers seems to be that the life of the reduction gear as designed at that time would be in the neighborhood of 10 years. This perhaps doesn't bear directly on what John Reed said in regard to the life of gears used at the present time. He was speaking of mill drives.

C. J. Klein: In connection with the wearing out of the gear teeth, I can state one case where the excessive misalignment of the motor in relation to the drive overtaxed the flexible coupling and caused the pinion teeth to wear out due to excessive end thrust.

The lubricating factor cannot be overlooked either.

P. T. Vanderwart*: Mr. Burr put the question of the relative strength of the double helical gear with a solid section at the V versus the construction with the open or non-closed V section. It seems to me that while the open construction gives four possible ends to break off, if the factor of safety is there on the outside ends it is equally there on the inside ends. The construction with the slot down the center of the double helical gear makes for better oiling and therefore increases the life of the gear from the wearing standpoint.

The question of wear is probably going to be more important in the future as gear manufacturers begin to find out where they can cut down strength to meet competition. There will be a tendency to make them lighter and lighter. The speaker showed us a picture of one that had been running for 12 years without noticeable signs of wear. That was one of the first mill drives built and probably had a large factor of safety compared with present gear drives. As construction becomes lighter to meet competition it is a question if we are not going to reach a point where the wear becomes a more important factor. It would be a good idea to accumulate data from the operating men, or other sources available, on the relation between wear and average and maximum running tooth pressures.

C. J. Klein: All our gear drives are designed to take two things into account. The first is the strength of the tooth and the next is the wearing of the tooth. A gear can be designed 40 per cent lighter for strength than it can for wear. We have formulas for determining the width of the lace and this is always taken into account. As soon as you squeeze the oil from between the teeth you have metal to metal contact and you are up against wearing.

P. T. Vanderwaart: Now is there any further discussion.

On motion of a member, Mr. Klein and Mr. Talbot were extended a rising vote of thanks for their very interesting and thorough discussion of the subject presented. The motion was seconded and by a rising vote carried. Meeting adjourned.

*Plant Engineer, Shoemaker Bridge Company, Pottstown, Pa.

†General Furnace Company, Philadelphia, Pa.

*New Jersey Zinc Company, Palmerton, Pa.

*Direct Current Hoist and Trolley Control for Ore Bridges**

By N. L. MORTENSEN†

ORE bridges are a very important factor in the handling of ore, both at the unloading docks, where they are used for unloading and distributing the ore, and at the blast furnaces, where they are used for filling hoppers or transfer cars for the furnaces.

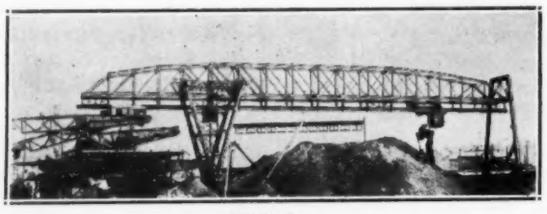


FIG. 1.

A typical ore bridge is shown in Fig. 1. On modern bridges, the motors and machinery for hoisting and for moving the trolley are located on the trolley itself, and the operator rides in a cab attached to the trolley. The controllers are also located in the cab,

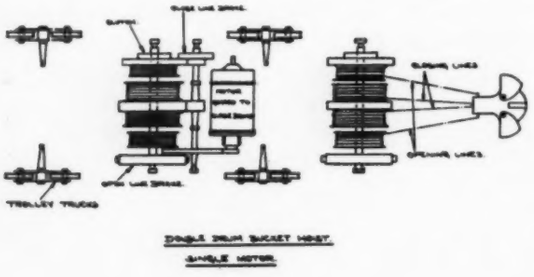


FIG. 2.

either in the same room as the operator or in a separate compartment.

Considering first the hoisting equipment, the grab buckets used in connection with these bridges are suspended and operated by two ropes—the closing line

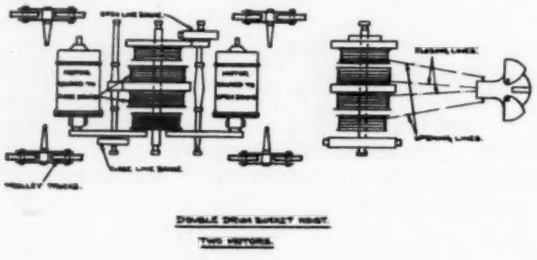


FIG. 3.

and the holding or opening line. These lines are operated by hoisting drums, which are driven by one or two motors. Different arrangements are used for the operation of the drums. The closing line drum is generally geared to a motor, but the opening line drum can either be operated from this same motor by means of a clutch or a separate motor can be provided. Frequently two small motors are used in place of one large motor, so that either one, two or four motors can be used in connection with the hoisting machinery. Each one of these arrangements has its advantages, and the number of the motors used depends upon the construction of the hoist and to some extent upon the size of the motors necessary.

A single motor double drum bucket hoist is shown in Fig. 2. A clutch is provided between the closing

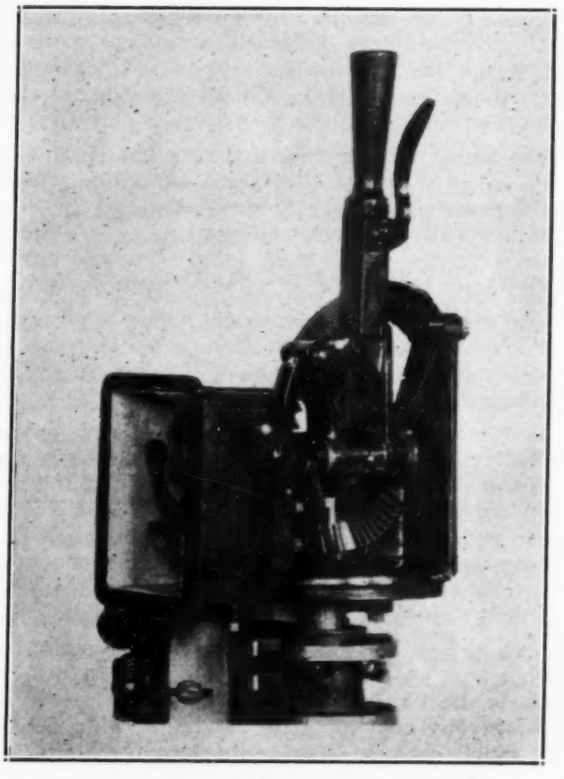


FIG. 4.

line drum and the holding or opening line drum and a brake on the holding line drum. This hoist also shows a brake for the closing line drum; on a number of modern bridges, however, this brake is not used; the motor is held by setting the clutch between the two drums and setting the opening line brake. On some bridges an additional clutch is used between the motor and the closing line drum, so that this drum can be revolved by releasing this clutch and the clutch between the closing and opening line drums.

Fig. 3 shows a two-motor hoist with a motor geared directly to the closing line drum and another motor geared directly to the opening or holding line

*Presented before Chciago District Section, Nov. 21, 1924.

†Designer and Engineer, Cutler Hammer Manufacturing Company, Milwaukee, Wis.

drum. Holding brakes are provided in connection with both the opening and the closing line drums. The work in closing and opening is done primarily by the closing line motor, and in hoisting and lowering the two motors are operated together.

The holding brakes and the clutch are either magnetically or air operated. Provision must be made on

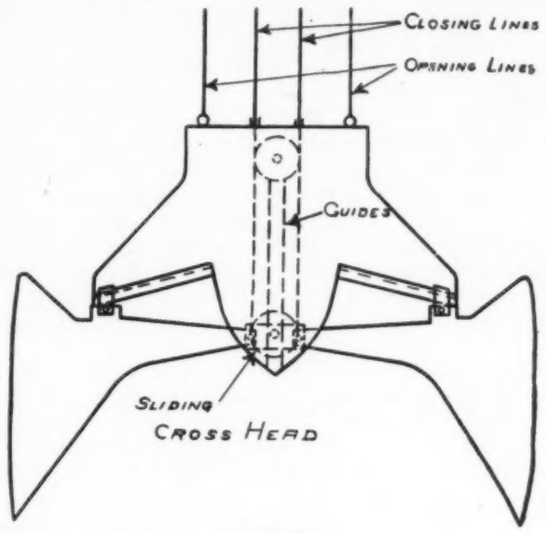


FIG. 5.

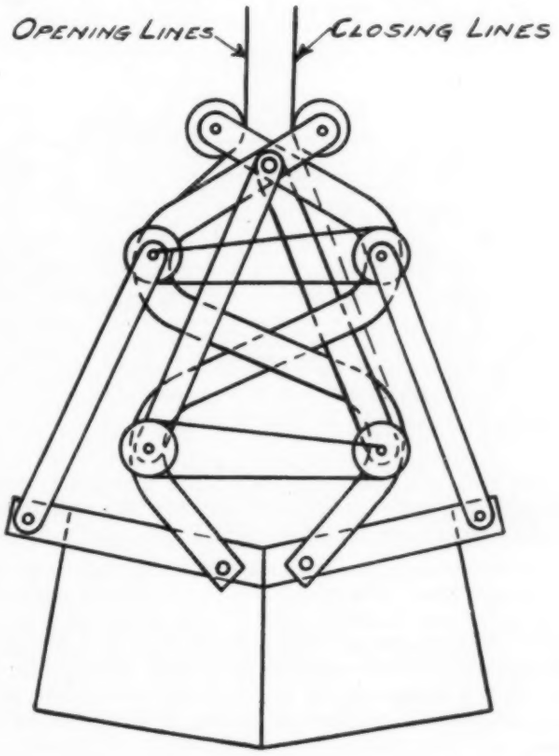


FIG. 6.

the control apparatus for operating the brakes or clutches. Where a single motor is used, the clutch between the two drums is generally operated from a grip contact in connection with the master lever. Fig. 4 shows the construction of a master provided with a grip lever. By pressing this lever, the clutch is released and the brake on the opening line is set. By releasing this lever, the two drums are clutched together for hoisting and lowering. Where the clutch and brakes are magnetically operated, the solenoids

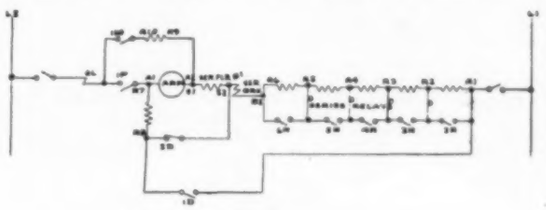


FIG. 7.

for them are operated by means of contacts in conjunction with the grip lever. Where they are air operated, valves are provided in connection with the grip lever for controlling them.

Where independent motors for the two drums are used, they can either be operated from two masters or from one master provided with a grip lever similar to the master for single-motor hoists. The two masters give a more flexible operation, but requires the additional lever for the operator to handle.

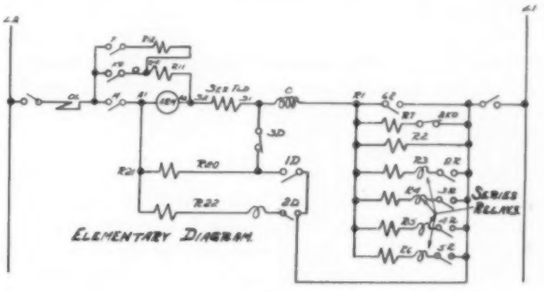


FIG. 8.

It is practically impossible to discuss ore bridge control without giving consideration to the construction of the grab bucket itself. Many different makes of buckets are in use, and while they vary considerably in construction, the characteristics of all of them are similar to either of the two types shown in Figs. 5 and 6. They are all constructed so that they will close by pulling in the closing line and will open by releasing this line. The opening or holding line can be kept more or less stationary during opening or closing of the bucket. On both buckets, the closing

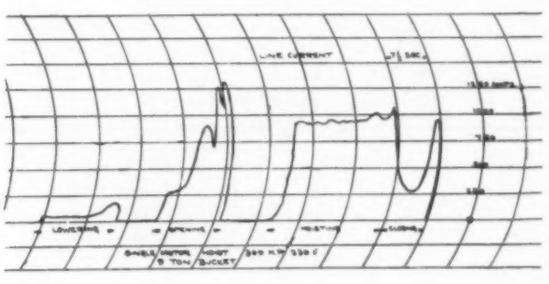


FIG. 9.

line is run around sheaves, which are pulled together for closing. On the bucket per Fig. 5, the holding line is fastened directly to the main frame, whereas on the bucket shown in Fig. 6, the closing line is also

passed around sheaves. Therefore, with the bucket per Fig. 5, only the weight of the blade and part of the weight of the ore tend to open the bucket, whereas on the bucket per Fig. 6, the opening line tends to open

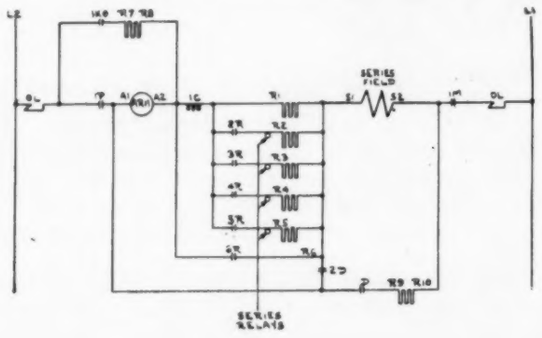


FIG. 10.

the bucket as the weight of the bucket pulls the sheaves of the opening line together. This latter bucket, therefore, exerts a considerable pull on the closing line during opening, as the total weight of the bucket and ore helps to overhaul the closing line motor. The pull exerted by the closing line in case of the bucket per Fig. 5 is comparatively less. On the other hand, it is necessary to have considerable slack in the opening line at the beginning or pay out slack during closing in the bucket similar to Fig. 6; this bucket, however, is not as sensitive to tension on the closing line when the bucket is lowered open.

The motors used for these hoists are practically all of the series wound type, and on modern bridges dynamic braking is always used for lowering. The controllers must be designed to operate and control the motors while opening and closing the bucket and during hoisting and lowering. The motors rotate in the same direction for closing and hoisting and in the opposite direction for opening and lowering. The requirements for hoisting are that it should be possible to take up slack without undue jerk, to close the bucket at the proper speed, and to accelerate and hoist the bucket and load. These requirements, however, are similar for different makes of buckets and can be met with a multi-speed controller, which will enable the operator to obtain the proper closing speed. The requirements for opening and lowering depend upon the characteristics of the bucket and the construction of the hoist, and provision must be made for checking, retarding and lowering the loads, and it is the ar-

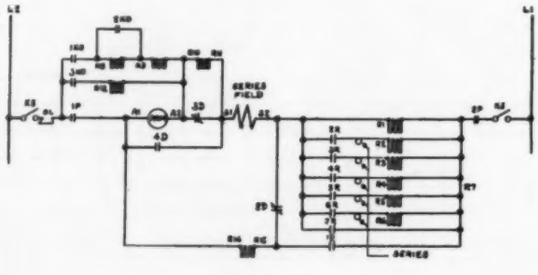


FIG. 11.

rangements made for opening and lowering in which the main difference in the construction of these controllers exists. Fig. 7 shows a dynamic lowering controller that contains all the features necessary in connection with this type of equipment. This diagram shows a series brake used in conjunction with the motor. However, this brake can also be shunt wound or air operated. The control establishes the usual connection for power in closing and hoisting by closure of the 1-P contactor, and the necessary accelerating contactors are opened and closed, depending upon the position of the master. For opening of the bucket and for lowering, the 1-D and the 1-KO contactors are closed, establishing a kick-off and dynamic braking connection, and the accelerating contactors 2-R to 6-R are closed in sequence in retarding the motor. In the "off" position, the circuit is closed around the armature and series field by means of the 2-D contactor. While this controller has all the features required for operating the bucket, it is generally necessary to make additional provision for satisfactory operation, because the controller shown provides for a relatively low kick-off torque for opening the bucket. The current during kick-off divides through the armature and the series field, and with the master thrown

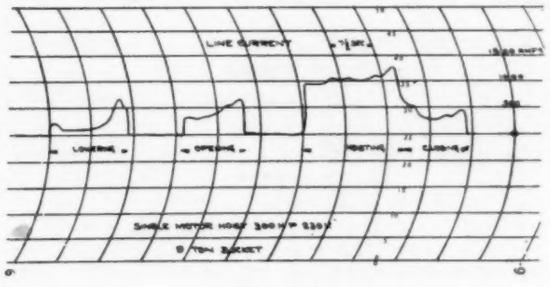


FIG. 12.

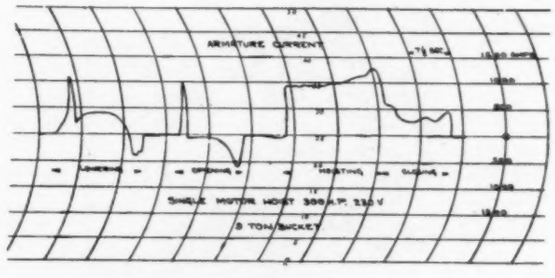


FIG. 13.

to the last position, relatively little current is passed through the series field, and consequently a comparatively low torque is obtained.

In order to obtain the most torque with a controller of this kind, it is necessary to divide the current so that is it practically equal in the armature and the field. Fig. 8 shows a controller for a single-motor hoist, which is arranged to give high kick-off torque; the motor being series wound, the clutch and brake are air operated. This controller is used in conjunction with the bucket shown in Fig. 5. The connections for hoisting are similar to those previously described, and in the "off" position the circuit is closed around the armature and series field by the 2-D contactor. In opening, however, the current is more equally divided between the armature and the field, and automatic operation is obtained during acceleration of the motor; this is done by first opening the 1-D contactor, and in this way increasing the resis-

tance in the armature circuit. When the motor starts to accelerate, this contactor is again closed automatically, and after the motor has accelerated to a higher speed, the field is weakened by cutting in resistance by opening of the 2-KO contactor. In this way, high torque and speed during the kick-off period are obtained, which results in quick opening of the bucket. During lowering, both the 1-D and 2-D contactors are opened, 2-KO contactor is closed, and the controller functions similar to the one previously described.

Fig. 9 shows the line current taken by a 300-hp., 230-v. motor with a controller of this type during a complete cycle; that is, closing, hoisting, opening and lowering. The size of bucket used is 9-ton and the speed is approximately 200 feet per minute.

While this controller has provision for opening the bucket quickly, you will note that the kick-off current

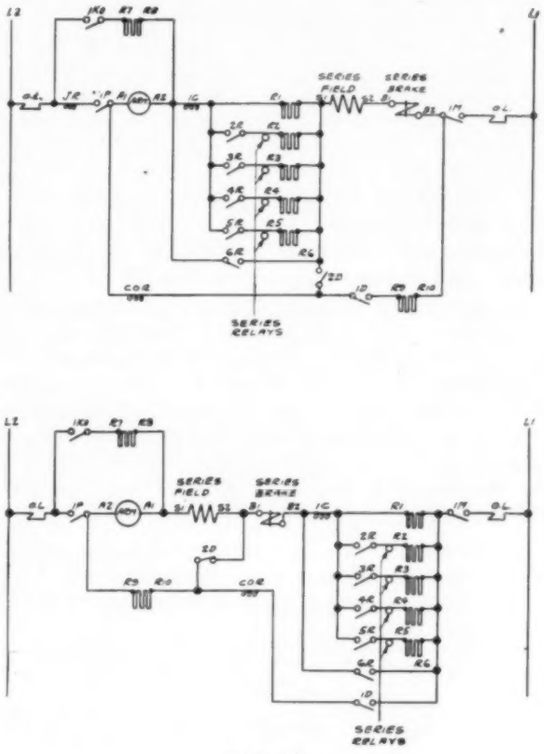


FIG. 14.

is relatively high. The reason for this is that the kick-off current is divided between the armature and the field, and the torque is, at the best, about one-half of that which can be obtained if the same current is passed through both the armature and the field. Fig. 10 shows the connection for a controller where provision is made to pass the armature current through the series field during opening. Here again, the closing and hoisting are the same as the controller previously described. For opening, however, the 2-D contactor is closed, and the armature current therefore passes from the armature through the 2-D contactor, through the series field to the other side of the line. For lowering, the 2-D contactor is opened, and therefore the connection during opening is the same as for ordinary dynamic lowering controller.

Fig. 11 shows a controller similar to Fig. 10. With this equipment the 1-D and 3-D contactors are opened during opening of the bucket and the 4-D contactor is closed, so that the armature current passes through 4-D and the series field. A step of resistance, R10-R11, is provided around the 3-D contactor and acts

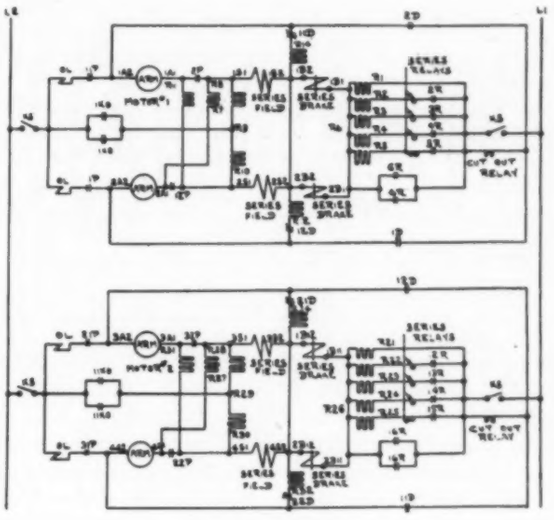


FIG. 15.

as an armature shunt, so as to limit the speed during opening to a safe value.

Fig. 12 shows the line current obtained with a controller of this kind used in conjunction with a hoisting equipment similar to the one on which the curve shown in Fig. 9 was taken. You will note that the closing peak is less than in the previous curves, and the closing time is somewhat longer. This latter may be due to different operating conditions or it may be due to the way the operator manipulates the master. The kick-off current during opening, you will note, is materially reduced, and is about one-half of what is shown in

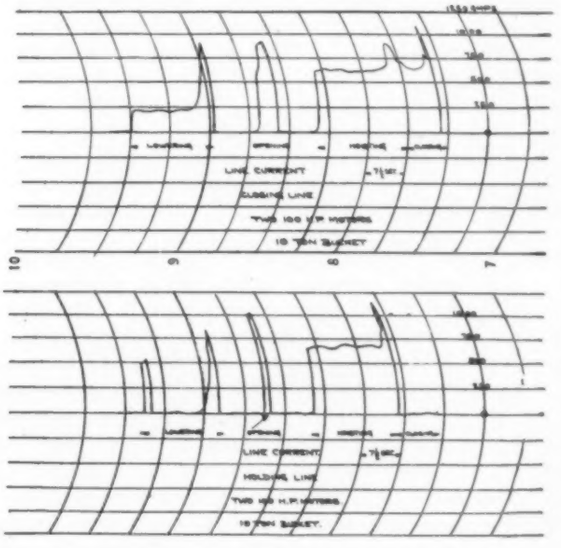


FIG. 16.

Fig. 9. Fig. 13 shows the armature current on this same equipment. The hoisting current is the same. During opening, however, it will be noted that the current is reversed and also that it is practically zero

during the latter part of this cycle. The peak during the last part of the opening cycle is the dynamic current taken by stopping the motor. The curve for lowering also shows the kick-off current, the reverse

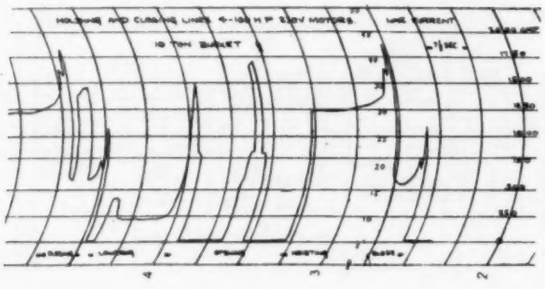


FIG. 17.

current for dynamic, the reduction of this current when the operator hits the ore with the bucket, and the increase caused by stopping the motor.

The connection for a control for a two-motor hoist when used in conjunction with the bucket per Fig. 5 is shown in Fig. 14. The motors are series wound provided with series wound brakes. The connections for closing and hoisting are similar for both controllers, and power is obtained by closing the P and M contactors. For opening and lowering, however, the connections are different. The closing line is so arranged that the armature current for opening is passed through the series field by the closure of the 2-D contactor in order to obtain the high kick-off torque by relatively low current from the line. On the opening line controller, this provision is not necessary, and the controller in general is, therefore, similar to the one described in Fig. 7. During lowering, the 2-D contactor is opened on the opening line controller, and the lowering connections are, therefore, the same on both equipments. The main reason for using different control connections for the two motors on equipments of this kind is that with an equipment like the one shown for the closing line controller, all accelerating resistance will be in the motor circuit in case of failure of power. This objection, however, is readily overcome by the holding line controller, as this controller is provided with the usual dynamic braking arrangement, and the 2-D contactor will close the dynamic circuit around the armature and series field. With the above combination, therefore, arrangement is made to insure quick opening of the bucket at a relatively low current, and the equipment is also perfectly satisfactory from the safety point of view. The resistance layout for these controllers is arranged so as to insure that the bucket can be lowered open and the closing line motor made to operate at the same speed as the opening line motor with less overhauling torque from the bucket. The controllers are either operated by one or two masters. Where one master is used, the operation is very much similar to the single motor equipment.

The connection of a controller for a four-motor hoist used in conjunction with a bucket having characteristics similar to the one shown in Fig. 6 is shown in Fig. 15. The controllers for the closing and holding line are practically alike, and the main difference between them is in the resistance layout. One of the problems encountered on hoists of this kind is to make the motors properly divide the load during dynamic. The characteristics of series motors are such that they will divide the load equally during hoisting, as in case one motor should attempt to take more load than the other, it will slow down and the other motor will speed up and in this way equalize the load. During dynamic braking, however, just the opposite takes place, and in case one of the motors takes a greater part of the load, it will slow down, increasing the unbalancing still more. It is therefore, advisable to take special precaution in balancing the motors during lowering, and this can be done either by paralleling the series fields or by an arrangement similar to the one shown in the above diagram. During hoisting, the contactors 11-P, 21-P, 12-P and 22-P on the closing line controller and similar ones on the opening line controller are closed and the armature of each motor is, therefore, in series with its own series field. In lowering, however, the 1-D, 2-D, 11-D and 12-D contactors are closed and all of the P contactors are opened. With this connection, resistance steps R7 and R11 on the closing line controller give an arrangement whereby the fields and armatures of the two motors are cross connected, so that if one armature tends to slow down and take more current, it increases the field strength of the other motor, and with this connection the motors will be balanced in lowering, the same as they are in hoisting. A similar connection is obtained on the opening line controller with resistance R17 and R21. With the exception of this arrangement the controllers in general are practically identical with the ones shown in Fig. 7.

Figs. 16, 17 and 18 show the line and armature current for a 10-ton ore bridge with a controller as shown in Fig. 15. The hoisting speed is approximately 250 feet per minute. The four motors used are each 100 hp. 230 v. The curves were not taken simultaneously, and therefore the time of the various operations may not check exactly for the different curves. They represent, however, a fair average of what can be expected on normal operation.

Fig. 16 shows the line current for the complete cycle for the two closing line motors and the holding line motors. In comparing the power taken for clos-

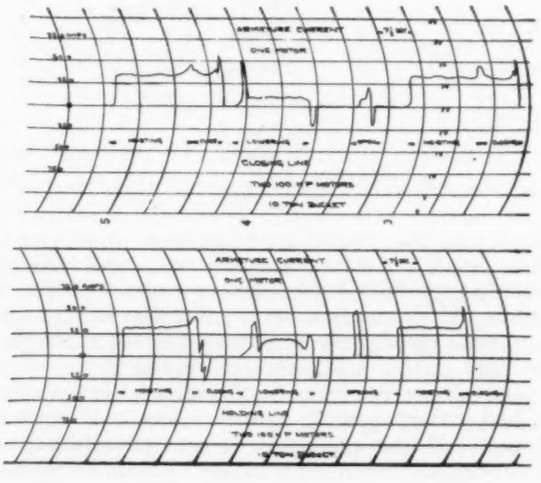


FIG. 18.

ing by this equipment with the equipment shown in Fig. 9, it will be noted that the closing line current is higher. Of course, it is a somewhat larger bucket and the speed is somewhat higher, but that does not

account for all the difference, and apparently the torque for closing this bucket is higher than what is required for the bucket per Fig. 5. The curve shows that in this cycle the holding line motor is not operated for closing. In opening, the closing line is thrown to kick off, and the holding line is thrown to power, and you will note that the time of opening is comparatively less than what it is on the curve previously shown. The lowering cycle shows that the holding line motors generates more current than the closing line motors, which does not take any current from the line except when the controller is thrown to the "off" position for stopping.

Fig. 17 shows the combined current for the holding and closing line for all four motors. This curve shows two hoisting cycles, and on the second one it will be noted that there is an additional peak during closure. This is due to paying out slack on the holding line motors.

Fig. 18 shows the armature current for one of the closing line motors and one of the holding line motors. It will be seen here that for opening the closing line motor is released, but after it is started, the motor actually retards the opening line. The time of opening can be varied considerably by different manipulation of the master, and if the bucket is opened by closing the motor alone, the time of opening will be increased. The second cycle of the curve for the holding line motor also shows the reverse current and kick-off for paying out slack.

It is general practice to lower the bucket at a higher speed than when hoisting. The current during lowering is less than during hoisting, and motors will, therefore, stand a higher speed. In retarding at high speed, however, it is necessary to cut out the resistance gradually, as otherwise a high current peak will be obtained, which will increase the field strength and this in turn will increase the counter-voltage, and the combination of the high current, voltage and speed

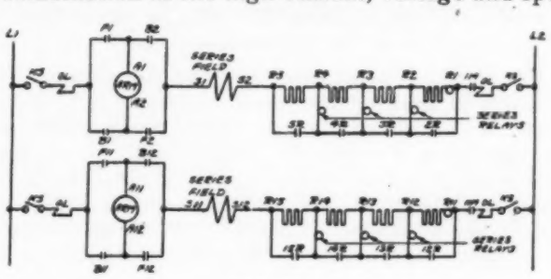


FIG. 19.

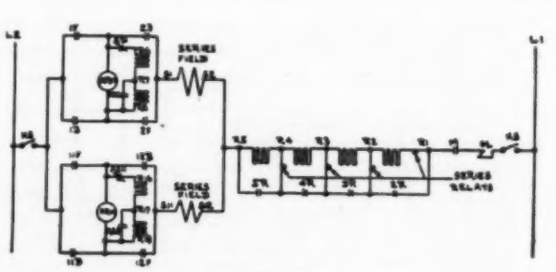


FIG. 20.

will cause sparking of the commutator. After the motors have decelerated down to normal speed, they can commutate the same current peaks as during accelerating in hoisting. Provision should therefore be made for limiting these current peaks on dynamic. This can be done either by separate resistance or it can be taken care of in the control circuit by so arranging the connections that some of the accelerating relays are effective in lowering only.

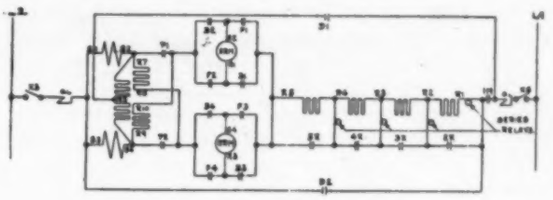


FIG. 21.

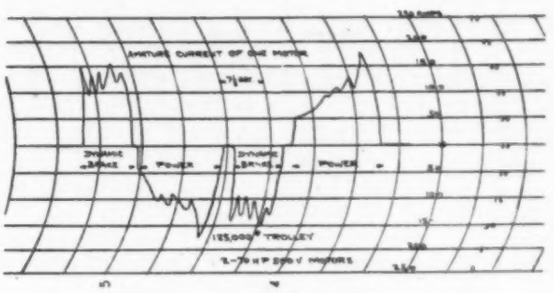


FIG. 22.

The control equipment for the trolley must be so constructed to properly start, accelerate and stop the trolley and load. The trolley motion is generally handled by two or more motors geared to the trolley wheels. The motors are practically all series wound, although compound wound motors have been used to some extent. Holding brakes of either the magnetic or air operated type should be provided. These brakes should be so arranged that they will stop the motor in case of failure of voltage. It is also desirable to provide limit switches to cut off power and apply the brakes if the trolley is run too near the end of the bridge. In general, however, it is desirable to stop on the motor rather than on the brakes on account of the large amount of stored energy which has to be dissipated during stopping.

A number of different controllers have been used on the trolley motion, such as straight reversing type, with or without plugging, reversing type provided with armature shunt, reversing type with dynamic arrangement, and series-parallel type, with or without dynamic braking. All of these types of controllers have their advantanges and disadvantages. The plain reversing controller with plugging for stopping is the simplest. The main objection to this type of control is that it is rather difficult to gauge the exact stopping point, as there is no definite point between plugging for stopping and acceleration. It has been our experience that where such controllers are provided, the trolley was generally stopped on the brakes when the operator moved over the boats for loading or over the hopper in case of unloading. In dumping the ore on the pile, this controller is very simple in operation, as it is only necessary for the operator to throw the master controller from one direction to the other, and the controller automatically takes care of reversing. This feature, however, may not be as important as might seem at the first, as the operator is not very busy at this time and the dumping does not have to be very

accurate, and he generally has sufficient time to manipulate any type of controller. The dynamic braking controller is somewhat more complicated than the straight plugging controller. It is, however, easier

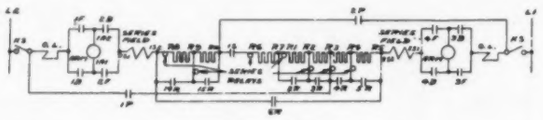


FIG. 23.

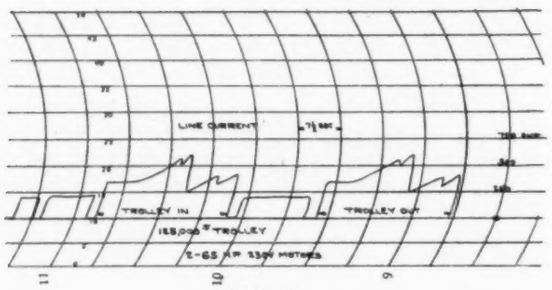


FIG. 24.

to obtain more accurate stops with this type of controller than it is with straight plugging. The armature shunt controller is somewhat in between these two. Series parallel controllers are rather complicated, but they are used to some extent on bridges with high speed where it is desirable to obtain fairly accurate slow speed for short quick movements. Power is also saved during acceleration with this type of controller compared with straight parallel equipments.

Fig. 19 shows a reversing controller with plugging for two motors.

Fig. 20 shows a reversing controller provided with armature shunt. For slowdown, the accelerating contactors are opened and the armature shunt contactors AS1 and AS11 are closed on the first point of slowdown, and AS2 and AS12 on the second point.

Fig. 21 shows a controller arranged for dynamic in connection with two series motors. This controller will give power and dynamic braking in both directons. Provision is here made by means of the P-1 and P-2 contactors and resistance steps R6-R7 and R9-R10 for cross connection between the armature and series field, similar to the two motor dynamic lowering hoist controller. Contactor D-1 is used for energizing the series field from the line during dynamic This is to insure quick building up of the counter-voltage. If self-excitation only is relied upon, the voltage will be rather slow in building up. Contactor D-2 establishes a dynamic connection in conjunction with reversing contactors, and it is necessary to reverse the armature connections from power to dynamic in order to obtain proper relation between armature and series field.

The curve shown in Fig. 22 indicates the armature current for a motor used with a controller of this kind. This curve was taken on a coal bridge, and the motors are 70 hp. 500 v. This curve shows quite clearly the higher peaks on dynamic due to the increased field strength in building up of the counter-voltage. If the motor was stopped on the brake the dynamic current would not obtain, and if the equipment was stopped by plugging, the current now taken for dynamic braking would be represented by current taken from the line.

Fig. 24. shows a series-parallel controller. The motors are first connected in series by means of the reversing and 1-S contactor, and are then accelerated to the full series position when 6-R closes. The S-1 contactor is then opened, the P-1 and P-2 contactors are closed, and 6-R is opened, connecting the motors in parallel. By this sequence of operation, torque is maintained during the transition period.

Where series-parallel controllers provided with dynamic for stopping are used, the series field can either be included in the dynamic braking circuit or it can be energized directly from the line.

Curve 24 shows the line current for two 65 hp. 230 v. motors driving a trolley. The weight of this trolley is 125,000 pounds and the speed is approximately 1,000 feet per minute. It can be readily seen from these curves that the current during the first part of the acceleration is about one-half of what it would be if the motors were connected in parallel.

Fig. 25 shows the armature current on one motor on a similar bridge. This curve was taken on a different bridge than the one shown in Fig 24, and although the values are somewhat different, the general shape of the curves is about the same.

The connection for a four-motor trolley controller is shown in Fig. 26. The motors in this case are compound wound and the controller is arranged for dynamic braking. For power, the P contactor is closed and either the forward or reverse contactors and the necessary accelerating contactors under control of the series relays. For dynamic, the D contactors are closed, and the S contactor is used for partly energizing the series field. Fig. 27 shows the power and dynamic for four 50 hp. motors with a controller of this type. The readings were taken outside the reversing contactors, so that the power current for forward and reverse both show in the same direction, and the same with the dynamic current.

The schemes of connections and the curves shown illustrate in general the main requirements of these bridges and what can be considered more or less average operating conditions. There are, of course, a number of different ways these results can be obtained, and there is, therefore, a considerable difference in the controller layouts. As far as the curves are concerned, operating conditions, adjustment of

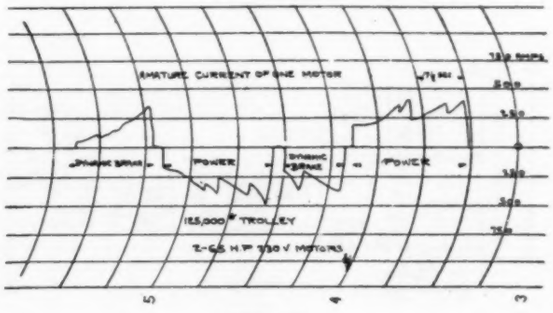


FIG. 25.

the controllers, and manipulation of the master by the operator have considerable bearing on them. We believe, however, that the curves as shown are more or less typical for the different kinds of bridges.

The controllers for these equipments are generally of the magnetic type, so that each equipment consists of a control panel with the necessary resistance and a master controller. The control panel is made up of the necessary contactors mounted on unit slates supported by pipe or angle iron framework. The resistance is separately mounted and consists of a number of grid frames. The master is of the multi-speed type, arranged with straight line or radial drive. Limit switches are frequently used in connection with both the hoist and trolley motions. The motors range in size from approximately 50 to 300 hp. and the service is rather severe, the machine making on the average one trip per minute.

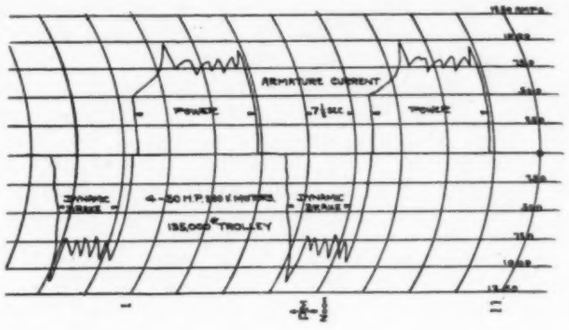


FIG. 26.

As far as the relative merits of the different types of equipment are concerned; that is, whether one motor or two motors are used, and the different arrangements of the trolley, we consider this a very difficult problem to decide, and what is best for one installation may not necessarily be best for another. Each type has its advantages; the operating conditions, the construction of the bridge itself, the features worked into the hoist, the size of the bridge and the size of the motor, all must be taken into consideration.

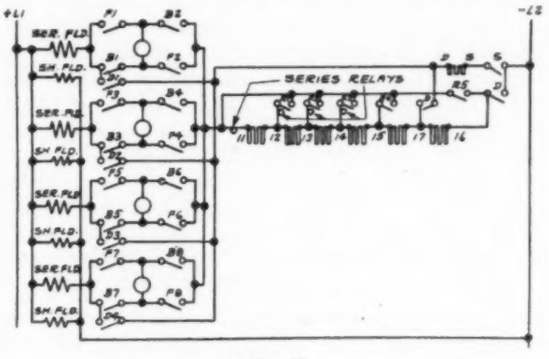


FIG. 27.

DISCUSSION

H. W. Eastwood*: The paper this evening presents a very live topic, but it really should have been presented in Cleveland rather than in Chicago. Most of you are no doubt acquainted with the frightful mortality among ore bridges in the Lake Erie district in the past several months. Two were lost in Lorain in the great cyclone which you have all read about, and two were lost a couple of weeks earlier, one at Ashtabula and one at Conneaut, making a total of four bridges destroyed in the Lake Erie district in the past six months, all due to wind storms.

This brings up a question which has not been touched upon n any of the papers this evening, that is the proper type of equipment to use to best control and protect the bridge moving gear of an ore bridge. One of the plants which is preparing to replace one of the bridges destroyed this summer is considering the use of shunt motors to drive the bridge. You will readily see the idea behind this proposal. If the wind tends to drive the bridge, the bridge will drive the motors and the motors will regenerate, thereby exerting a retarding torque which will prevent the bridge from attaining a dangerous speed. I would like to inquire if any of the operating men present tonight have had experience with shunt motors in such service.

Another idea, which is actually being applied on a bridge now in process of construction, is to use series motors and controllers providing armature shunt connections operating in conjunction with centrifugal speed governors. When the bridge exceeds a safe speed the centrifugal governors will automatically establish armature shunt connections, thus causing the motors to exert a retarding torque and limit the speed of the bridge to a safe value.

I had an opportunity several months ago to examine the driving wheels of a bridge which was wrecked in the Lorain cyclone. At the time of the storm these wheels were locked by means of a powerful friction brake on the driving mechanism and the flat spots on these wheels were conclusive proof that they did not roll. The force of the wind was so tremendous that it actually slid the structure along the track. Under such circumstances, it is evident that nothing you can do with the controller will save the bridge. A mechanical lock of some sort must be provided.

A recent and apparently a very effective bridge moving gear is the rack and pinion drive. With this system racks are put down along side of the track rails at each end of the bridge, and firmly anchored to the piers. This is not as expensive as it sounds, as the racks can be made, for example, of a series of heavy angles with steel pins for teeth. The pinions which engage with these racks are mounted on the bridge and trucks and are driven through worm gear reductions and powerful friction brakes are provided which lock the mechanism when the bride is at standstill. With this system you do not depend upon the traction of the track wheels. The machine is actually geared to the road. Since none of the track wheels are driving wheels, small inequalities of diameter cause no trouble and since the structure is positively geared to the runway, when the gearing is locked, the structure cannot be moved except by a force so terrific as to tear up the runway or strip the gearing. Two bridges with this sort of drive are in operation in the Lake Erie district and a third is in course of construction.

I thank you.

F. R. Burt*: It would perhaps not be digressing too far to say a few words about the different types of motors used on cranes and on similar applications.

*District Manager, Cutler Hammer Manufacturing Company, Cleveland, O.

*Engineer Westinghouse Electric & Manufacturing Company.

There is occasionally some misunderstanding regarding the basis of rating these motors and the advantage to be gained in rating by using open or forced ventilated machines.

Motors of this type are given several time ratings, but those most used are the half hour, one hour and five hour ratings. The first is used for crane service, the second for mill auxiliary service and the third for any service where the basis of application is the calculation of the root mean square load or heating effect of a given cycle of operation. The half hour and one hour ratings are more or less conventional. It would be hard to find an application where the motor starts cold, carries an intermittent load equal to the rating of the motor for a half hour, and is then shut down and allowed to cool before starting another cycle. This is what would be necessary in checking the half hour rating. The root mean square or heating effect of a load over a period of several hours determines the size of a motor except in some cases where the maximum momentary torque is important and when hour or half hour ratings are specified, the application has usually been made by comparison with other similar installations. On special or doubtful applications it is necessary to calculate the root mean square load of the cycle and select a motor with a corresponding root mean square capacity.

Any motor has a certain amount of thermal capacity. That is, it is capable of absorbing a certain amount of heat without raising the temperature to an unsafe point even if no heat is carried away. If an open and enclosed motor of the same frame are operated under the same load conditions it will be found that their temperatures will rise at about the same rate for a certain length of time, since the rise will depend almost entirely on their thermal capacities. For this reason the half hour rating of a given frame is about the same whether it is open or enclosed. As operation under the above conditions continues the capability of the machines to dissipate heat becomes a factor and the temperature rise of the open motor becomes slower than that of the enclosed one.

The fact that the open and enclosed motor has the same half hour rating is misleading, since the open machine actually has a greater root mean square capacity and will carry a greater load without overheating. Just how much advantage the open frame has is dependent on the size. On the smaller frames the advantage may be only ten or fifteen percent, while on the larger sizes it may be fifty percent.

The load an open motor can carry is roughly proportional to the square of the weight. An enclosed motor depends entirely on radiation for cooling and this is proportional to the surface. The load it can carry then is proportional to the surface which in turn is proportional to something less than the square of the weight. As the weight increases then the load it can carry goes up faster if it is open than if it is enclosed. A very small motor will carry practically as much load enclosed as it will open, while on a large motor a great part of the rating is sacrificed by enclosing. In fact there is a limit to the size of machine which can be enclosed since a point is reached where the surface is not sufficient to radiate the heat generated by the constant losses alone.

On the larger frames where enclosing means a large sacrifice in capacity, another possibility—that of forced ventilation—presents itself. Where it is possible to pipe clean air to the motor from some other point a much smaller machine can be used. The root mean square rating of an enclosed forced ventilated motor is about the same as the one hour rating enclosed and unventilated.

C. J. Smith*: The ore handling machinery at South Works, being the result of an evolutionary process, consists of a variety of styles and electrical equipment. The oldest rigs yet in service are the Hoover & Mason unloaders with the inclined trolley runway. These machines were originally equipped with steam engines, operating that way for four or five years before being electrified. The original control equipment was straight reversing, air brakes being used to limit the speed of the trolley and grab bucket on lowering, a scheme depending on the judgment of the operator and one which resulted in a great deal of trouble due to overspeeding. These machines were rewired several years ago and dynamic braking features incorporated. The speaker of the evening, Mr. Mortenson, presented a paper on ore bridge controls which was published in the February, 1923, procedeings of our society, which deals at some length with these unloaders. The rigs have the following motions—boom hoist, bucket opening, bucket closing, twister and bridge. Of these the bucket opening and bucket closing controls are of most interest, both of them being dynamic lowering. The grab is carried on a hook on the trolley to the desired point over the hold of the boat where the trolley is stopped and held by air brakes. The grab is then unhooked and lowered into the boat. During the time the trolley is traveling down the incline it is retarded by dynamic braking on the three 40 horsepower closing line motors. When the air brakes are set to hold the trolley at the lower end of its travel, dynamic is also applied to the two 40 horsepower motors on the opening or holding line, giving dynamic braking on all five bucket motors. In order to unhook the bucket from the trolley a quick start lowering is necessary and contactors are provided which on kick-off cause the armature current as well as the shunted field current to travel through the series field. This conditions obtains for the time required to unhook the grab and then the normal lowering circuit is established, with the armature and field currents following parallel paths.

The newer type unloaders have horizontal trolley runways, the operator riding in the cab. These rigs have the following motions — boom hoist, trolley, twister, bucket closing, bucket opening and bridge. The boom hoist controller gives dynamic lowering and is equipped with a traveling cam screw type limit switch to prevent over travel. The bucket opening and closing motions are equipped with dynamic lowering, one 150-hp. motor being used on each motion. The grab is of 8-ton capacity ataining a hoisting speed of more than 200 feet per minute and making the round trip from the boat to the pockets in less than a minute. The trolley is equipped with 3 50-hp. motors with straight reversing control, air brakes being used to stop the trolley.

The older ore bridges were equipped with Sprague control which has since been replaced. These bridges are equipped with two 80-hp. motors on each of the bucket-opening and bucket-closing motions, the capacity being 15 tons and the hoisting speed 140-180

*Assistant Electrical Engineer, Illinois Steel Company, South Works, Chicago, Ill.

feet per minute. Straight reversing control is provided, retardation on lowering being obtained by the use of air brakes. Originally these brakes were air set but have been changed to spring set, air released. The control is arranged so that first point lowering operates an air valve releasing the brakes. An auxiliary contact on the air valve completes the control circuit to the directional contactors. This scheme introduces a time element during which the brakes are releasing, before power is applied to the motors. Failure of air pressure renders the hoist inoperative. The trolleys, equipped with three 40-hp. motors, have straight reversing control, with air brakes for stopping. The control consists of individual reversing contactors and common accelerating contactors and resistors, with the addition of one step of resistance in each individual motor circuit, which is the last step to be cut out and whch is intended to limit circulating currents between the motors. The bridge motion is controlled by two masters, one on each group of pier motors. The bridge is constructed to allow for a skew of 150, and a skew limit switch provided which cuts the power off the motors if this is exceeded.

The newer bridges are similar to the older ones except skewing feature of the bridge is eliminated. Skew limit switches are provided which cut off the power within very small limits of skewing. In addition resistors are provided which are automatically cut into the circuit of the pier motors which tend to lead, by a mechanical device actuated by the skewing of the bridge. These bridges are equipped with two 100-hp. motors on each of the opening and closing motions, dynamic lowering control being provided. One master switch is provided for the control of each of these motions. The two motors are served by a common parallel connected resistor, with the addition of special features to insure the balancing of the two motors during lowering. In hoisting two series motors divide the load due to their inherent characteristics of slowing down with increased load. On dynamic lowering the reverse is true, that is if one motor tends to assume more of the load it will slow down and aggravate the unbalanced condition. To prevent this the control is arranged to cross-connect the motors so that an increase of armature current in one motor strengthens the field of the opposite motor.

The trolleys are equipped with three 50-hp. motors with control similar to that described above for the older bridge trolleys. Air brakes are employed for stopping the trolleys, being the only application of air on the newer bridges.

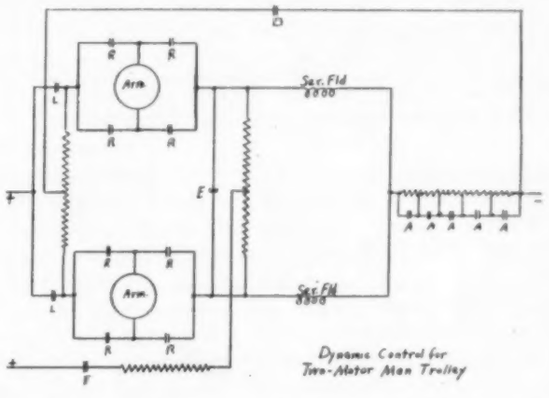
The trolley air brakes on the older bridges are applied to the truck wheels by a railway type brake, consisting of a cylinder which applies shoe brakes to the two adjacent truck wheels. On the newer installations the air pressure applies shoe brakes to a brake wheel carried on the armature shafts. The use of air brakes for stopping the trolley gives the greatest possible flexibility of control in stopping the trolley at a desired point. In addition to this feature the electrical control is reduced to its simplest form, effecting a saving of approximately 40 per cent over dynamic retardation and a corresponding saving over plugging control for the same purpose. From a safety standpoint the air brakes afford an unparalleled system, being independent of the action or failure of anyone of a great number of contactors, relays, etc. These ore bridge trolleys, weighing with load about 250,000 bs., and attaining a speed of 700 feet per minute, require the absorption of tremendous amounts of energy in the apparatus whose function it is to stop this mass. The stopping of the trolleys by either plugging or dynamic braking therefore adds materially to the heating of the motors. If the motors are loaded near capacity this additional load may well be the straw to break the camel's back. Our experience with air brakes shows very good life and low maintenance on the brake shoes, the usual performance being at least one complete ore season before renewals are necessary.

A. J. Whitcomb*: In this discussion, I would like to give some of the details and factors that caused the change from a dynamic braking control to a plugging control on the main trolley of a crane in which I had some interest in the operation of.

In order to help visualize the factors that caused us to make the change, let me briefly review the essential features of dynamic and plugging controls.

If a d.c. motor, while running, has its armature disconnected from the line and then short-circuited through a resistor, with the field remaining excited, the motor acts as a generator and circulates current through the armature and resistor. The energy absorbed in the resistance of the armature and its external circuit is translated from mechanical energy. This form of braking is commonly termed dynamic braking.

From the above definition we see that there are three essential features of dynamic braking: (1) The armature must be disconnected from the line, (2) It must be shorted through resistance and (3) the field must be excited. Let us examine a typical schematic diagram of a dynamic-braking control for a two-motor trolley. Power to start this arrangement of motors is



applied through the line contactors L, and the reversing contactors R. The motor is accelerated by means of the accelerating contactors A. When dynamic braking is to be applied, the line contactors L are opened, thereby disconnecting the armature from the line. The contactor F is closed to separately excite the series field. This gives quicker action in braking and results in a more uniform application of braking torque.

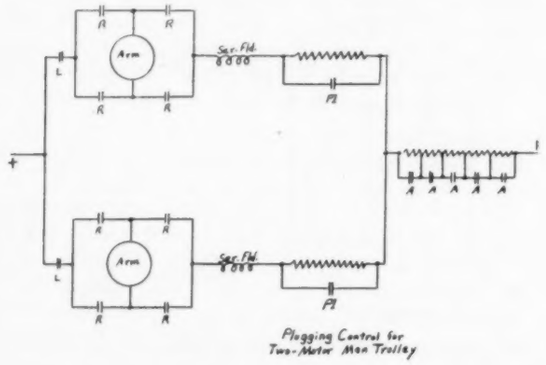
During dynamic braking the motors act as generators and since we are furnishing the equivalent of shunt excitation through contactor F and the equivalent of series excitation from the dynamic braking

*Formerly with Mark Manufacturing Company, Chicago, now with Industrial Engineer, Chicago.

current, we have, during the braking period, two compound wound generators operating in parallel. Therefore, it is necessary to provide an equalizer between the machines while they operate as generators, otherwise one generator will do all of the braking. This is accomplished by means of the contactor E. This equalizer connection could be done away with by cross connecting the fields with the armatures, but this would involve the use of two other contactors and still further complicate the control.

Let us compare the dynamic braking control with the plugging type of control. In a plugging control the retarding torque is developed by reversing the armature connections and applying power to the motor. This results in temporarily adding the motor counter-voltage to the line voltage; the sum of these two voltages causes a current to flow which develops a torque tending to rotate the armature in the opposite direction. This brings the armature to a stop and starts it in the reverse direction. An important distinction between dynamic braking and plugging should be noted here — dynamic braking exerts a retarding torque which decreases with the speed of the armature. Dynamic braking slows down the motor but will not bring it to a complete stop. Plugging exerts a negative torgue which brings the motor to a complete stop and will start a negative torgue which brings the motor to a complete stop and will start it in the reverse direction if the power is not cut off. This is an important advantage of man-trolleys as will be shown later.

Let us examine the essential features of a plugging control. Power is applied through the contactors P and the reversing contactors R. The motor is accelerated by the contactors Pl and A. Retarding and stopping the motor is accomplished by reversing the armature by means of the opposite set of reversing contactors. The contactors Pl are open during plugging thereby inserting extra resistance in the plugging circuit to restrict the plugging current peak to a safe value. The reason for two resistors in parallel instead of having one resistor is that this causes an equal division of load between the two motors while plugging.



Plugging Control for Two-Motor Man Trolley

Comparing this scheme of control with the dynamic layout, it will be seen that both types have two power or circuit breaker contactors, eight reversing contactors and four accelerating contactors. In addition to this, the dynamic control has a shunt excitation contactor F, an equalizing contactor E and the dynamic circuit contactor D. The plugging control has in addition only the two plugging contactors Pl, which in reality give the plugging control an additional accelerating point. Hence we see that the dynamic type of control requires an additional contactor as compared with the plugging type.

Let us now compare the things that might cause failure of braking in either type of control.

(1) If the dynamic contactor D fails to function, the dynamic circuit is left open, no braking is obtained and the trolley coasts. With the plugging type of control there is no similar contactor to fail.

(2) If the equalizer contact E fails to function, one motor will do excessive braking and lock the track wheels that it drives, thus skidding and doing little braking, while the other motor practically coasts. There is no similar contactor on a plugging control to cause a like reaction.

(3) If the shunt excitation contactor F fails to function, the dynamic braking torque will build up slowly to a value less than normal. There is no similar contactor to fail on a plugging control.

(4) If the armature reversing contactors on a dynamic controller fail to reverse, the dynamic braking current through the series field will buck the shunt excitation and practically no braking will result, in fact the trolley coasts. If a plugging controller is used the trolley will continue under power. However, the reversing contactors are more likely to fail to reverse in the case of a dynamic control than in a plugging type. The reason for this is that in order to keep the dynamic circuit closed when the master is in the center or off position many dynamic controllers energize the closing coils of both sets of reversing contactors. The set of reversing contactors that were last closed naturally will stay closed and the mechanical interlock will hold the other set open. Now if the reversing contactors are large, heavy and somewhat slow in action, it is possible for the operator to jerk the master from a power position to the off or center position so quickly that the reversing contactors will not have a chance to reverse. Since the armature was not reversed the generated voltage of the armature causes a current to flow through the series field opposing the shunt excitation, which bucks the field and thus the dynamic retarding torque is killed and the motor coasts. Of course, the operator should not bring the master from a power point to the off position so quickly. However, he will do it, for I have been on trolleys of several cranes when it was done, and the trolley coasted into the bumpers.

You may say that hese four troubles, that I have outlined as being liable to happen on dynamic control, are more or less imaginary and at the most their chance of happening is very remote. Let me say that I have had all of them happen, not once, but several times during my experience with coal and ore bridges.

We have already developed the fact that plugging control requires one less contactor than a dynamic control. Let us now compare the masters required for the two types of control.

For a dynamic controller having three speed points the master will have eleven fingers. The master for a corresponding plugging type control will require only nine fingers, which means less maintenance and less chance for trouble.

The master for a dynamic control having three speed points will have 15 operating points; first, there will be a central or off point on which both the magnet

brake and dynamic braking will be applied; on each side of this will be three dynamic points; on each side of the dynamic points will be a coast point, and beyond each coast point will be three power points. Compared with this the master for a plugging control will have central or coast position and only three power points on each side of it, a total of seven points, which is less than half the number of points required by the master for the dynamic control.

Let us compare the operation of the two masters. As has been said previously, the master for a dynamic controller has power points, a coast point and dynamic braking points on each side of the center or off position. When the operator is running on a power point and wishes to coast, he must bring the master to this coast point. If he wishes to apply dynamic braking the master must be moved to another position. If he wants to bring the trolley to a positive stop after it has slowed down, he must bring the master to the center position at which the magnet brake is applied.

As can be readily seen the operator must use judgment and care each time he moves the master; moving the master a little too far destroys the particular operation that he is trying to secure.

It is quite possible for an operator's attention to be called to something beyond his immediate duties and in making the next move with a master having so many different operating points, he may apply power when he should apply braking or vice versa or he may use the braking points on the opposite side of the master, all of which is liable to result in a smash if the trolley is close to the bumpers.

Compare this with the master used with a plugging type of control. There is only one position on each side of the center point. If the operator has the trolley moving under power and he wishes the trolley to coast, he brings the controller to the off position. If he wishes to bring the trolley to a stop he throws the master to the oppsite side of the off or central position.

It is easy to see how much simpler this master is to operate than the master for the dynamic type of control. And since the operator of an ore or coal bridge has three other masters to manipulate, this means quite a little, particularly as we do not get the class of operators that we used to.

Dynamic braking is more effective while the motor is running at normal speed than it is when the motor is running slow. This is because the retarding torque is dependent on the armature current flowing in the dynamic circuit, which in turn is dependent on the armature speed and the field strength which are both decreased by the slowing up of the motor due to the retarding torque. To compensate for the reduction in braking torque at the lower speeds, steps of resistance in the dynamic circuit are successively cut out so as to offset the reduction in dynamic voltage. When the trolley is moving at a very slow rate of speed, the dynamic braking torque is not very effective. While it will eventually stop the trolley, the use of a shoe brake for a final stop will be found preferable if a quick accurate stop is desired.

The plugging type of control, on the other hand developes a high retarding torque as the motor approaches standstill. When the motor speed has reached a low value the plugging current will have a value approximating full load current and the accelerating relays will cause the plugging contactors to close thus cutting out the plugging resistance and leaving the armature across the line with the accelerating resistance in series with it. The result is that when the motor approaches zero speed there will be a torque equal to normal starting torque tending to stop the motor. Consequently, a shoe brake is not needed to bring the trolley to a quick accurate stop.

The fact that a plugging control will reverse the motor if not shut off, is sometimes called a disadvantage. I do not think it is a disadvantage in the case of a man trolley. For instance in taking ore or coal directly out of a boat and dumping into the pile fewer manipulations of the trolley master are required with a plugging control. The master is thrown in the direction to move the trolley from the boat to the pile. As the trolley nears the pile the master is thrown to the extreme opposite side with the result that the trolley is slowed down, stopped, reversed and started towards the boat without any attention on the part of the operator. This leaves the operator free to dump the bucket.

The dynamic control consumes less power than the plugging type of control, due to the fact the armature is disconnected from the line and generates the dynamic braking current. However, in the case of a series motor with its series field shunted across the line through resistors, there is some power used. I do not thing the power question is of any account in the steel mills. The increase in power consumption is greatly over-balanced by other considerations.

To summarize the advantages that plugging control has over dynamic control we may say the following:

(1) The plugging control has fewer contactors and a simpler master which results in less upkeep and maintenance.

(2) The operation of the master of a dynamic control is more complicated and requires more thinking and judgment on the part of the operator.

(3) The control scheme of a plugging type of control is simpler and there are fewer causes for braking to fail to function.

(4) The plugging type of control does not require a shoe brake to bring the trolley to a quick accurate stop, where as, with the dynamic type of control it will be found preferable to use a shoe brake for making the final stop.

I would like to say a few words about the scheme of control for the trolley brakes. Since coast points are required on a trolley control, shunt brakes are used except where air brakes are supplied. On a bridge which had a man trolley using dynamic control, I found that the shunt brakes were connected directly across the line and would set only in case of power failure. The trolley was slowed down on dynamic and plugged to bring it to a complete stop. This was unsatisfactory because the operator would sometimes plug the motors too soon and since no plugging resistance was provided the track wheels would skid or else violent jerking of the trolley would result. Moreover, it is desirable to have the shoe brakes under the control of the operator so we arranged the control to set the brakes on the off or center position of the master. This had the disadvantage, however, that the brake was in constant use and was no longer an emergency proposition. Also, I found that the operator would apply the brakes while the trolley was run-

ning at a good speed, instead of waiting until the trolley was running slow. The result was that the combination of dynamic braking and the magnet brake would lock the wheels and either violently jerk the trolley or else skid the track wheels.

The control was rearranged shortly after this for plugging service for the reasons that I have previously enumerated. In the first arrangement three off points were provided on the master. The center point was to apply the magnet brake and the point on each side of this brake point was a coast or drift position. This proved unsatisfactory because it required the operator to hunt for the drift points and it made it necessary to apply the brake and release it before plugging.

The master was then changed so that there was only one drift point, which was the center or off position of the master. The brake was operated from a foot switch. This was unsatisfactory because the operator would both plug his control and apply the brake simultaneously with the result that the wheels would lock and skid.

The final solution of the problem was to interlock the brake control from the foot switch with the off position of the master, with the result that the brake can be applied only when the master is in the off or drift position. This forced the operator to plug for regular operation and to use the brake only for emergencies.

This made what was practically a fool-proof proposition for the operator could not possibly mistreat the trolley in his method of handling it. The master switch handle could be manipulated from one side to the other as fast as the operator desired and no harm would result. Uniform braking was obtained in every instance. And the operator was unable to plug and apply the magnet brakes simultaneously.

I have referred to changing from a dynamic to a plugging type of control. This is much simpler than might at first be supposed. In making such a change it is only necessary to change the drum in the master switch, rearrange the resistors and change the connections to some of the contactors. The ease with which this may be done will greatly surprise one.

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*Electric Industrial Locomotives**

By FRANK E. FISHER†

IT is becoming more apparent every day that most of the transportation problems around steel mills, blast furnaces, foundries and other industrial plants, can be most satisfactorily solved by means of the electric locomotive. To be sure, there are many arguments for and against electric equipment, and there are some cases where electric locomotives are not as suitable as other types of equipment. In the majority of cases, however, that we have investigated we have found that some type of electric locomotive will do the job better than anything else.

In studying a transportation problem, there are many things which enter into the solution of that problem and these are the first things that I want to talk about tonight.

The first and most important is the track itself. In the first place, the weight of the rails limits the size of locomotive that can be used. Good practice for minimum rail section is an allowance of 10 lbs. of rail weight per yard for each ton of locomotive weight on each driving wheel. For example: the minimum rail weight for a 20-ton, four-wheel locomotive is 20 times 10 divided by 4, or 50 lbs. per yard. Table No. 1 shows the minimum and recommended rail weights for various weights of locomotives both in the four-wheel and six-wheel types.

While this table shows weights of rail for four and six-wheel locomotives, problems can be solved where a heavy locomotive is required and the rail section is light, by operating two four or six-wheel locomotives in tandem. This has been done in many cases.

If you will refer to the table, you will find that the recommended weight of rail for a 10-ton locomotive is 40 lbs. If there is a long haul and a large tonnage to be moved, it may develop that work could be more economically done by a 20-ton locomotive, than by one or two 10-ton locomotives running as individual units. In this case, two 10-ton units could be connected in tandem to operate from one controller, thus securing the 20-ton locomotive and still running on a 40 lb. rail.

Track gauge has a great deal to do with the solving of the problem. There are many industrial railroads which were installed for hand operation and which have been added to, year by year, until the distances have become so long that some kind of mechanical haulage is necessary. With hand haulage, small cars and narrow track gauges were used in order to make the loads within the limits of one man power.

When a locomotive becomes necessary, the problem of getting sufficient horsepower in any type of locomotive is a serious one. By a narrow track gauge, I mean 18 in. to 30 in. A great many industrial rail-

TABLE No. 1.

Weight of Locomotive, Tons	Weight of Rail, Pounds per Yard			
	Four-Wheel Locomotive		Six-Wheel Locomotive	
	Minimum	Recommended	Minimum	Recommended
2	12	20	..	..
4	16	25	..	..
5	16	25	..	..
6	20	30	..	..
8	25	30	..	..
10	30	40	20	30
13	30	50	25	40
15	40	50	30	40
20	50	60	40	50
25	60	70	50	60
30	75	80	60	70
35	80	85	70	80
40	85	90	75	85
50	95	100	85	95

*Presented before Chicago District Section, December, 1924.

†Engineer, Goodman Manufacturing Company, Chicago, Illinois.

roads are 24 in. As an example of the complications which arise with a narrow gauge railroad, I want to tell you of a problem which we have recently solved which is very interesting:

There is a large lead mine in Missouri having an underground haul of from three to four miles on a grade of 3 to 5 per cent against the empties. It was necessary to drive the main entry or roadway of the mine through solid rock and the cost of this work, even though the rock that was taken out was ore bearing, was very great. The result was that the entry was made as small as convenient. Hand tramming was used at first and later mules. A gauge of 24 in. seemed at the time the installation was put in and for some years after, to be the best gauge from all standpoints. In order, however, to escape the high maintenance cost of light track, 60 lb. rails were installed.

Two or three years ago the daily tonnage had become so large that it was necessary to install electric equipment. The long hauls necessitated large motor capacity and the tonnage required made it necessary that the locomotives be designed for heavy drawbar pulls. It was finally decided to ask the manufacturers for a 13-ton locomotive to operate on this narrow gauge of 24 in.

For reasons which I will explain later, it was deemed advisable to equip this locomotive with 90 horsepower motors. Now, locomotive motors for mine service and for industrial work run at an average speed of 400 rpm. at full load. You can readily see that a 90 hp. motor running at this low speed becomes too large to use with a single gear reduction between the wheels and special construction had to be resorted to. If you use double reduction gearing it sets the motors very high in the air, making the locomotive approximately 5 ft. high. On account of the high position of the heavy weight of motors, the center of gravity of the locomotive is an appreciable distance above the rails. It is, therefore, difficult to keep a locomotive of this type on the narrow track. Various companies have attempted to solve the problem in various ways and I will tell you a little later how it was solved by one of them.

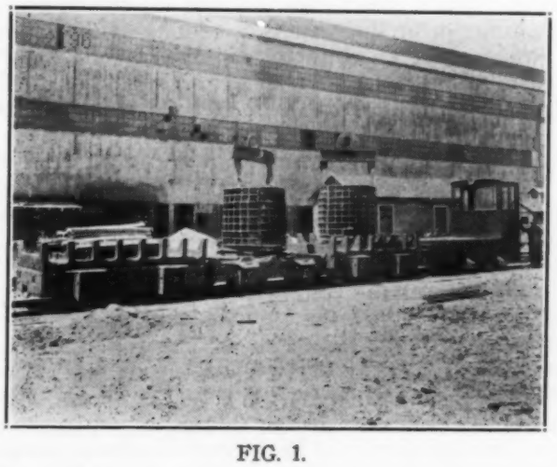

FIG. 1.

Smaller locomotives running in sizes from 5 to 10-tons can be built by several different methods. The motor shaft can be placed paralled with the track and the drive can be made either through worm or bevel gears, provided the wheelbase can be made short enough to take the curves. It will be seen, therefore, that track gauge has a great deal to do with the solving of the problem.

The contour of the track determines the weight and design of the locomotive to a larger extent than most of us think. If the curves are short it becomes necessary to use a small wheel and short wheelbase. If you shorten the wheelbase, you must arrange your motors for outside hanging; that is, with the motors both outside of the axles, or they may be hung in tandem; that is, with the two motors on the same side of their respective axles. They cannot be central hung, that is, with the motors between the two axles.

TABLE No. 2 — MINIMUM RADIUS OF CURVE

Wheel Base, Inches	Diameter of Wheel, Inches					
	18	20	24	30	33	36
	Minimum Radius of Curve, Feet					
20½	8	8	..	..	..	..
24¾	8	9	10	..	..	..
27¼	9	10	11	..	..	..
30	10	11	12	..	..	..
32	10	12	13	14	..	..
36	12	13	15	16	17	17
40	13	14	16	17	18	19
42	..	15	17	18	19	20
44	..	16	17	19	20	21
48	..	17	19	20	22	22
52	..	..	20	22	24	24
56	..	..	22	24	26	26
60	..	..	23	26	28	28
62	..	..	..	27	29	29
66	..	..	..	28	30	31
72	..	..	..	31	33	35
84	..	..	..	36	39	39
96	..	..	..	41	44	45
108	..	..	..	47	49	50
120	..	..	..	52	55	56

Table No. 2 shows the curves which locomotives equipped with various wheel diameters and wheelbases can negotiate without difficulty. This table is a fair guide for checking up performance of a given locomotive on a given track. It is well, of course, to make the radius of curvature as large as possible but in many instances this is as small as 9 ft. or 10 ft.

The grade of the track determines the weight of the locomotive. Each per cent of grade—that is for each raise of 1 ft. in a vertical direction for each 100 ft. of horizontal travel—increases the required drawbar pull by that per cent of the train weight. In other words, for each per cent of grade it will require 20 lbs. per ton additional drawbar pull. Furthermore, this grade decreases the drawbar pull of a locomotive by a percentaeg of its weight equal to the grade expressed in per cent. A locomotive that will pull 500 tons on a level dry rail will pull 324 tons up a 1 per cent grade, 234 tons up a 2 per cent grade, 182 tons up a 3 per cent grade, and 122 tons up a 5 per cent grade, while on an 11 per cent grade it will pull on 51 tons.

Curves have a marked effect upon the weight of the locomotive. It is good practice to allow from .8 to 1 lb. per ton per degree of track curvature. In most cases, however, in slow speed work such as is used in industrial railroads, the curve resistance can be neglected. It cannot be neglected in the case of high speed train service.

The types of switches used—that is point or stub switches—while they do not affect the weight of the

locomotive, do affect the performance, because unless the switches are of a substantial type, fast and sure in operation, the number of derailments during the day's work will appreciably reduce the amount of material handled.

The clearances through which the locomotive must pass, often determine the design of the locomotive. For example, there may be doorways, building columns, oven supports or other obstructions which are of such a permanent character that they cannot be moved, which will limit the width, height or length of the locomotive. The height of the coupling on the car, which has a marked effect on the drawbar pull of the locomotive, may require special design. It will be easily seen that if the drawbar height is above the center line of the wheels that there is a tendency to raise the opposite end of the locomotive about the near wheel as a fulcrum and the amount of this tendency depends upon the ratio of the height of the drawbar to the wheelbase. This turning moment takes weight off of the far wheel thus reducing the drawbar pull of the locomotive.

It is accepted practice today to use the following figures in determining the drawbar pull of a locomotive:

Chilled cast iron wheels:

Dry rails with sand, 25 per cent of weight on drivers.

Dry rails without sand, 20 per cent of weight on drivers.

Wet rails, 5 to 15 per cent of weight on drivers.

Steel tires or steel wheels:

Dry rails with sand, 33 per cent of weight on drivers.

Dry rails without sand, 25 per cent of weight on drivers.

Wet rails, 5 to 15 per cent of weight on drivers.

TABLE No. 3.

Nature of Product.....
Roadway:
Please sketch track system.
Track gauge.....inches.
Weight rails.....pounds per yard.
Length haul one way.....feet.
Per cent grade with load.....; length of grade.....ft.
Per cent grade against load.....; length of grade..... ft.
Minimum radius of curvature.....ft.
Equipment:
Weight of empty car.....lbs.
Capacity of car.....pounds.
Type bearings in wheels (roller or plain).....
What make cars are you using?
What are the limiting dimensions of locomotive?
Height .....inches
Width .....inches
Length .....inches
Work:
Nature of material hauled.....
Number of cars per trip.....
Number of trips per day.....
Length of working day.....
Total tonnage to be moved per day.....
What is your present method of haulage?.....
If animal haulage, how many animals used?.....
Power:
Current available (direct or alternating).....
If direct, the Voltage.....; capacity.....kw.
How much capacity can be spared for locomotive?.....kw.
If alternating, the Voltage.....; capacity.....kw.
phases .....; frequency.....cycles.
Can you use a trolley?.....
Can you use a third rail?.....
Can you use a storage battery?.....

We now have a brief resume of most of the factors which determine the weight of the locomotive. There are some other factors, however, which enter into the problem and which are outlined in Table No. 3, which might be called an Engineering Data Sheet.

After we have determined the weight of the locomotive, then our attention must be turned to the types of electric locomotives which are available for this service. So many industrial problems have been solved and so many ingenious devices have been used that almost any problem today has a precedent. For example, take a problem which was solved about three years ago:

The conditions were such that it was impossible to use the overhead trolley system; the temperature was such that it was impossible to use a battery locomotive and the fact that large billets, which were handled by cranes or electero magnets, were sometimes dropped on the track, made the use of a third rail prohibitive. The locomotive operated only once an hour and the standby charge for a gasoline or steam locomotive very greatly increased the operating expense. It was decided, if possible, to work out some kind of an electric haulage system. A contactor system was discussed. This method uses the rails for return and has a positive power line inside of conduit with a system of clapper type or magnetic switches which are energized by a magnet on the locomotive and which close only when the locomotive is over these contact boxes. This system, however, could not be used because the plant power house could not be grounded.

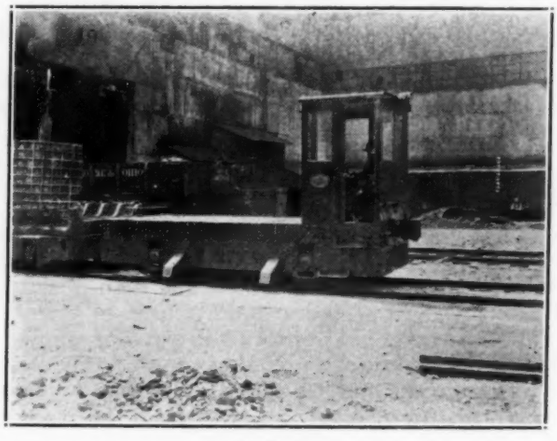

FIG. 2.

The scheme finally used was a trough, built below the ground, lined with concrete and provided with suitable drainage. On the sides of this trough are mounted positive and negative rails and a double shoe arm, hung from the side of the locomotive on a parallel motion, collects the current from these two rails and feeds it to the locomotive. The top of this concrete trough was closed by slabs of cast steel 3 in. in thickness with an opening of only 1¼ in. While the initial or installation cost of this equipment was very high, the upkeep cost of the system has been practically nothing to date and it has been in about three years.

Another installation which shows the need of ingenuity in solving some of these problems was a dryer tunnel system for bricks. The conditions of this problem were rather exacting. There were 55 tunnels and each tunnel had a capacity of 21 cars. The distance between the doors of the tunnel and a line of posts

next to a transfer track was only 8 ft. The temperature in the tunnels was 160 deg. F. Each tunnel had to be partially drawn, about every two hours. It required five men to push the 21 cars in the tunnel and sometimes it required more than five. The high temperature made successful lubrication of the cars very difficult even though they were roller bearing cars. The problem was further complicated by the fact that the cars as they went into the tunnel, were loaded with soft bricks and any jar of the cars would mark the bricks, making them unfit for use as grade "A". I have some lantern slides which I will show you a little later, showing how this problem was solved by means of an electric cable reel.

An electric cable reel is a device attached to a locomotive which permits it to run any distance up to 1,000 ft. away from the trolley or third rail circuit, and which lays down and picks up the cable without dragging it. It is a device used a great deal in the coal mines.

An entirely different type of problem is one that at first seemed to have been solved in a very expensive manner. The work to be done consisted of handling three to five loaded freight cars in a lumber yard and these had to be moved, every two or three hours. At first it would seem that a gasoline or steam locomo-

FIG. 3.

tive was the most suitable haulage unit. A trolley type of locomotive could not very well be used because it was necessary to go into buildings and an overhead trolley system would interfere with crane operation. A large storage battery locomotive was finally purchased and the deciding factor was the question of insurance of this lumber yard, which contained a considerable quantity of very valuable wood such as mahogany, teak wood, etc.

It will be seen from these few examples that there are a great many questions which must be considered in selecting the type or design of locomotive.

The problem is sometimes further complicated or the design determined by the fact that the only source of power is a.c. and to date there are very few problems in industrial haulage that can be handled by a locomotive equipped with a.c. motors. The sources of power by which a locomotive can be run are as follows:

(a) Overhead trolley system operating from 250 volt or 500 volt d.c.

(b) A third rail system.

(c) A surface contactor system.

(d) Special systems insulating both positive and negative rails, using trolley equipment.

(e) Storage battery.

(f) Combinations of storage battery and trolley or storage battery, trolley and third rail.

(g) Reel and trolley.

The conditions surrounding the problems as outlined above determine the weight and the general dimensions of the locomotive, but they do not take into consideration the type of control, nor the hp. equipment.

There are two types of control in general use on industrial locomotives under 25 tons; namely, "series parallel" and "series and parallel". In the first type of control the motors are arranged in series across the line voltage and with resistance in circuit on the first points. There are usually four points of resistance and then motors are arranged in parallel with resistance and finally in parallel across the line without the resistance. With this system it is necessary to always start with the motors in series.

In the second type of control, there are auxiliary points on the reverse handle which are used for changing the motor connections for operation either in series or parallel. With this type of controller the locomotive can be started with the motors in series or with the motors in parallel. In the case of wet rails this latter type of controller is often of great advantage. If the motors are in series and one pair of drivers slip, this motor running at a high speed and developing a relatively high counter E.M.F. prevents a large current supply from reaching the second motor just when it is needed, and the load cannot be started. With the motors in parallel, they operate independently and if one pair of drivers slip, the other will get current in an amount equal to its slipping point and you may move the load.

It is considered good practice on small locomotives up to 10 ton, to equip them with power at the rate of about 10 hp. per ton and in sizes from 10-ton to 25-ton with about 12 hp. per ton. These figures, however, are purely arbitrary and are based on the experience of the various manufacturers extending over a period of years. There are many factors which enter into the question of motor capacity on locomotives. If we reduce the hp. to a formula basis it will be as follows:

$$H = \frac{D \times S}{375}$$

H = Horsepower
D = Drawbar pull
S = Speed in miles per hour

For example: A locomotive which will develop 4,200 lbs. drawbar pull at a speed of 6 miles an hour will theoretically require 67.2 hp. If the locomotive is equipped with steel tires, this locomotive would have a weight of 8.4 tons and the motors in accord with the arbitrary figure of 10 hp. per ton, would be 80 hp. It will be seen from this formula that if the speed of the locomotive is reduced, the required hp. is also reduced.

There are other factors, however, that enter into the selection of proper motor power. Locomotive motor horsepowers are on the basis of a one hour 75 deg. C. block test with the covers open and this formula gives the required hp. without any mention of time. It is obvious that if there is a long haul which must be made without any rest between runs, that the one

hour duty hp. equipment will not be satisfactory. It is, therefore, necessary to take into consideration the time that various loads will be imposed upon the motors and make the proper selection of motor sizes for these values.

A study of the operating conditions in connection with the locomotive performance curves furnished by the manufacturers, will soon tell whether the motors are of adequate capacity or not. To show the wide variation in motor equipment on locomotives, please note the following comparisons:

A 15-ton locomotive running over a distance of 1,500 ft. once every four hours at a speed of about 5 miles an hour is equipped with two 75 hp. motors.

A 15-ton locomotive in ordinary mine service where the hauls are between 3,000 ft. and 4,000 ft. and trips require a drawbar pull slightly less or just equal to the rated drawbar pull, is equipped with two 90 hp. motors.

A 15-ton locomotive running on a two mile haul up a grade of about 2 per cent with trips that require about 10 per cent less than the rated drawbar pull of the locomotive and where the operation is such that the locomotive is running under load approximately 70 per cent of the time, is equipped with two 105 hp. motors.

A 15-ton locomotive handling trips which require about 80 per cent of full rated drawbar pull, running over a track 4 miles long and up a grade such that the load on the motor is practically continuous, is equipped with two 120 hp. motors.

It is obvious that the service for which the locomotive is intended has a great deal to do with the capacity of the motor.

In the case of a storage battery locomotive, the motor must be selected with reference to the battery and the battery must be selected in accord with the service. It is a well known fact that the nickel iron battery has a high internal resistance and where it is possible, especially on low voltage batteries, it is very desirable to have the resistance of the motor, the wiring and all external circuit parts very low to partially compensate for the high resistance of this type of battery. It is, therefore, often advisable to select a motor of excess rated capacity or horsepower in order to secure a low resistance motor.

The storage battery locomotive is here to stay for certain conditions and if the installation is made after a careful survey of all conditions, success is assured. The weak part of the locomotive is the battery and the difficult thing to determine is the amount of work that is expected to be done in one day. Switching work is especially hard to analyze because in order to determine the battery capacity the work must be reduced to ton miles.

A kwh. is equal to 2,654,000 ft. lbs. If we assume a car friction of 40 lbs. per ton, then the work required to move one ton one mile is 5280×40 or 211,000 lbs. or .0795 kwh. This is assuming, however, 100 per cent efficiency.

It has been found after a long period of years, taking into account average locomotive efficiency, average battery efficiency and an arbitrary allowance for switching and accelleration, that an average overall efficiency of about 45 per cent should be used. If we divide .0795 by .45 we get .175 kwh. per ton mile at 40 lb. train resistance, a figure which will provide ample battery capacity.

We have used this formula for a long time and have as yet to find one installation where the battery capacity is inadequate. The difficult thing to determine in each case is the number of ton miles of work to be done per charge of battery. It is an easy matter to determine the weight of the locomotive which will meet the maximum condition in a switching job. That is, we know whether the sidings and track lay-out are such that 1, 2, 3, 4 or 5 cars will be handled at one time, and we know the grades over which these cars will run.

The difficult thing to determine is the smaller amount of work to be done, how far the locomotive will have to run light, distances and number of times one car will be handled, etc. As a result we have tried to determine about what this work will be and then have sold the locomotive with a slightly larger battery capacity. However, most of the purchasers find sooner or later that it is necessary to increase the battery capacity. This condition can be met in two ways: First by making the battery boxes larger than are required at the time the locomotive is sold so that additional cells can be added without other changes to the locomotive except possibly rheostat connections. Second, by making the battery box of the removable type so that an additional battery can be on charge while the locomotive is in service. The usual speeds of battery locomotives are below five miles an hour. The rated drawbar pull and the hp. equipment runs from five to eight hp. per ton.

The electrical equipment is again determined by the service for which it is intended. The battery must be charged every night and any heavy draws for long periods on the battery reduce the capacity per charge. Storage batteries have recently been brought to a greater state of perfection than they were five years ago. Jar breakage is a thing almost unheard of unless a collision or other accident of unusual character takes place. The average lead battery is said by the battery manufacturers to have a life of about 44 months, in mine service which is very severe. There are cases where lead batteries in steel mill service have lasted as long as eight or nine years.

Edison batteries have also been in service as long as the lead cells. In case of the Edison batteries, it is necessary to insulate them very much more carefully from the battery boxes, since the outside of the can is "alive". The cells assembled in trays must be held secure against vibration or movement due to coupling or collision and the cells should be so placed in the locomotive that longitudinal shocks are taken on the liquid and not on the ends of the plates. All connections of lead batteries should be burned and each battery should be equipped with a suitable ampere hour meter so that the amount of charge in the battery at all times can be made by the operator. The larger size of battery locomotives should be equipped with an ammeter so that the operator can see when he is discharging the battery at rates which may be injurious.

Discharges of 10 times normal rate for short periods are not injurious to the battery but if they are maintained for five or six minutes and occur frequently, the life of the battery is materially shortened. If

the battery is given proper care and attention, that is, kept clean, not over discharged, charged in the proper manner as recommended by the battery manufacturers, kept watered and is not run or charged at excessive temperatures, good results may be expected from this type of equipment.

The thing to remember in connection with a storage battery locomotive is that it carries the power plant around on its back and con do only a limited amount of work per charge of battery.

For certain classes of work the reel and trolley locomotive can be used to advantage. For example, in quarry work where the end of the track is shifted from day to day and where blasting makes the use of an overhead trolley system impossible, reel equipment on the locomotive will permit the locomotive to run right up to the face without extending the trolley wire closer than 1,000 ft. Of course, in coal mine service this auxiliary piece of apparatus is invaluable because it is not necessary to put trolley wire up in the rooms or on some of the cross roadways.

FIG. 4.

Now let us assume the following conditions and work out a recommendation for a locomotive.

(a) Gauge, 42 in.

(b) Weight of rails, 40 lbs. per yard.

(c) Minimum radius of curvature, 35 ft. at switches.

(d) Roadway:

(1) Maximum haul, 1½ miles.

(2) Sidings, four, each 75 ft. long.

(3) Grade of 1 per cent for 600 ft. is against the loads, balance level track. All sidings and switches on the level.

(4) Switches are all of point type.

(e) Amount of material to be moved daily, 500 tons.

(f) Number of cars per trip, 10.

(g) Weight empty car, 4,000 lbs.

(h) Weight load in each car, 10,000 lbs.

(i) Car bearing, are roller type.

(j) Power available, 250 volts d.c.

(k) A trolley locomotive is desired.

(l) Cars are loaded in five minutes from hopper and unloaded in five minutes on trestle.

(m) Length of working day, 8 hours.

The first thing to determine is the weight of locomotive. The 10 car train will weigh 70 tons and since the grade is against the loads, the maximum required drawbar pull will be on the grade. The car friction with roller bearings may be assumed at 30 pounds per ton. If the bearings are kept well lubricated, it will run as low as 20 pounds. We shall, however, use the safe figure. This is the drawbar pull required to move one ton on a level dry rail. To this 30 lbs. must be added 20 lbs. for the 1 per cent grade, making a total required drawbar pull of 50 lbs. per ton. For a 70 ton train we must provide a running drawbar pull of 50 times 70, or 3,500 lbs. The locomotive will be equipped with steel tires; therefore, since it can exert a drawbar pull equal to one-fourth of its weight, it must weight at least four times 3,500 lbs. or 7 tons. The locomotive, however, loses drawbar pull on a 1 per cent grade, in an amount equal to 1 per cent of its weight. The nearest standard size of locomotive to 7 tons is 8 tons and this 8 ton locomotive can exert a 4,000 pound drawbar pull on the level and 3,840 pounds on the 1 per cent grade. This weight of locomotive is therefore satisfactory.

The next thing to consider is the time element. Since each train of 10 cars carries 50 tons of material, and 500 tons are to be moved in eight hours, there will be 10 trips; or a round trip must be made in 48 minutes. Time for loading and unloading totals 10 minutes, leaving 38 minutes running time to travel three miles. This means a maintained average speed of approximately 4¾ miles per hour. An inspection of the locomotive performance curve shows the speed of the locomotive at 3,500 pounds drawbar pull is 7 miles per hour. Since the return trip is with the empties, the round trip can be made with time to spare. There will be sufficient time for the motors to cool on the "empty" trip so that standard equipment of two 80 hp. motors will be O.K. The standard 8-ton locomotive has 30 in. wheels and a 48 in. wheelbase.

By referring to Table 2, it will be noted that the locomotive will negotiate a 20 ft. radius curve. By referring to Table 1, we finrd the recommendation of rail weight to be 30 pounds per yard. Since the track is built of 40 lb. iron, this feature is O.K. Since the gauge of 42 in. is within the limit of standard design, we need consider no special features. Our recommendation, is therefore for a standard 8-ton locomotive.

It will be seen from the foregoing discussions of the conditions surrounding electric industrial locomotives that each installation is a special problem and that unless it is carefully studied the best result cannot be obtained. If you have a transportation problem, however, I am sure you will find it interesting to say the least, and you may find it very profitable to carefully consider the use of electrical equipment. Industrial locomotives are available for operation on the various kinds of power mentioned above and in sizes from 1 to 50 tons and for operation on gauges from 18 in. to 60 in. I am sure that any of the manufacturers will be very glad to co-operate with you in securing the best type of equipment for your work.

Breaking Spindles for Main Roll Drives

By J. H. ALBRECHT*

THE problem of the protection of steel mill machinery against overloads is a very important factor in the operation and maintenance of our modern mills. In this respect the electrical engineer's problem is very much simpler than that of his brother of the mechanical department. The rapid development of electric protective devices has enabled the electrical engineer to protect his apparatus from almost every angle. The oil circuit breaker with its relays for high tension circuits enables him to protect the incoming lines to his main roll drive against overload, voltage failure or fluctuation and phase reversal. On d.c. drives the airbreak circuit breaker has been developed to such a point that it is very reliable. On auxiliary drives, the automatic control boards now in general use can be equipped with overload protection at a very small cost. The lesser power and light circuits can be protected by miniature breakers or by fuses. The refillable fuse is probably the simplest and cheapest protective device now on the market.

Not only do these devices quickly and safely disconnect the electrical apparatus from the line but they also permit service to be restored with a very slight delay and at practically no expense either in material or labor. The mechanical man's problem in protecting his equipment is vastly more difficult and on some types of drives heretofore, the difficulties have been practically insurmountable. On some drives, the electric protective devices will help considerably. On reversing bloom mill drives which are entirely d.c. the airbreak circuit breaker, between the mill motor and its generator, usually has an instantaneous trip and is fairly efficient in protecting both motor and mill against heavy overloads. Even in such cases, however, the flywheel effect of the motor armature may be sufficient to cause some damage particularly if a bad "cobble" should occur at the high speed. The writer has seen this happen on a modern bloom mill when the manipulator side guard on the side farthest from the operator had been torn loose by the split end of a bloom and had been carried back in the rolls by the reversing tables.

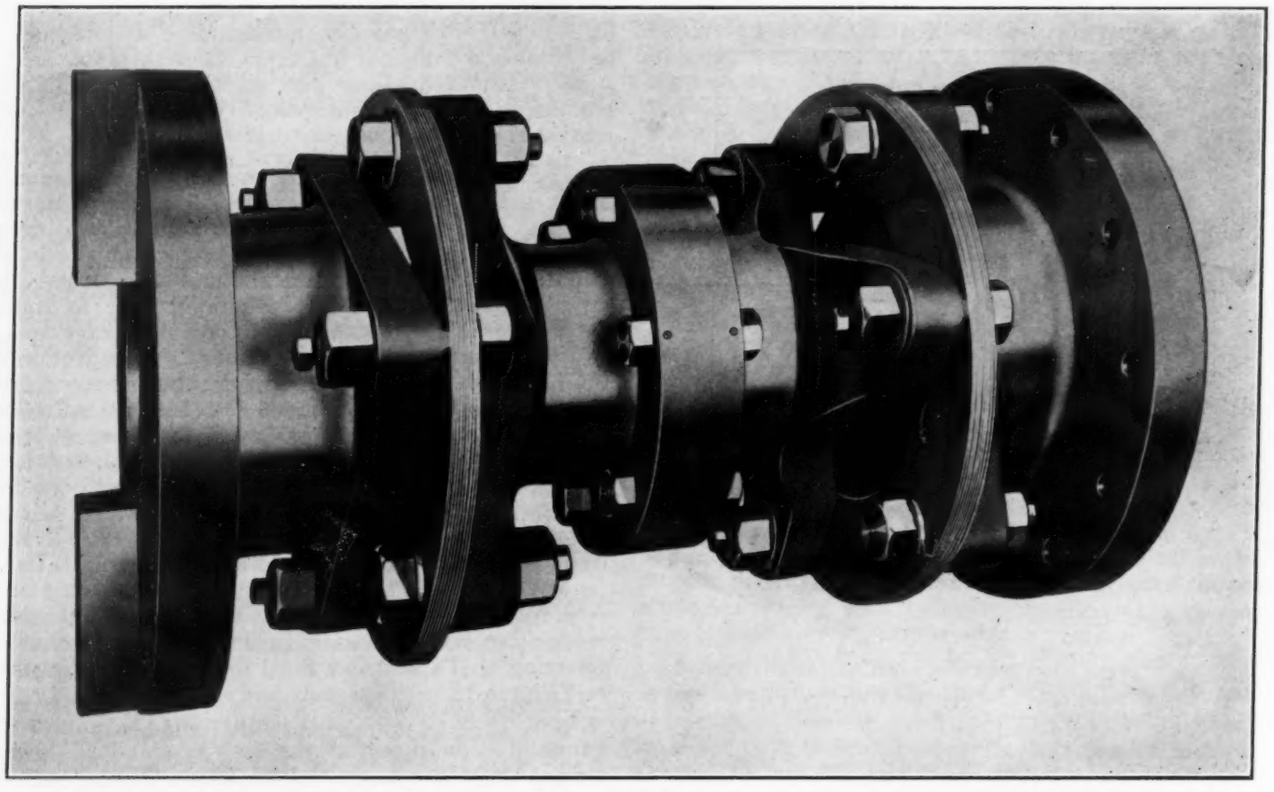

FIG. 1.—*Combination flexible coupling and breaking spindle 84-in. plate mill, Youngstown Sheet & Tube Company.*

On slow speed direct connected drives operating without fly wheels the proper electric protective devices on the motor will, in most cases, efficiently protect both the motor and the drive from dangerous overloads. If the mill and motor shafts, couplings, wobbler boxes, etc., are designed to carry approximately 250 per cent full load torque (based on motor rating), with reasonable factors of safety, the drive will probably operate satisfactorily.

The very great improvement in gear design and the better performance and lower cost of the high speed motor has led to the rapid adoption of this combination for main roll drives. A fly wheel is usually mounted on the high speed shaft between the motor

*Engineer, Thomas Flexible Coupling Company, Pittsburgh, Pa.

and pinion. The advantages of this drive are self-evident and the net operating result over a period of years has proven that this type of drive is logical and that it has come to stay. It has, however, added much to the problem of the mechanical engineer as his apparatus must now stand squarely on its own feet and he can no longer rely on the electric protective devices as in the case of the other drives. The fly wheel is a vast reservoir of useful energy. It appears to the electrical man as a great ally in protecting his motor, supply lines and power house against the shock loads of the mill. To the mechanical man, however, it appears as a vast reservoir of energy which his gears, spindles, wobblers, etc., may be called upon to absorb almost instantaneously. His calculations as to stresses in these parts are now largely shot as these stresses now depend upon how fast the mill tries to stop the fly wheel. He now has two courses open. He can design his drive details large enough to take care of the dissipation of the entire fly wheel energy. This will result in very greatly increasing the size and weights of all parts and would greatly increase the cost of the mill. The average engineer not familiar with steel mill practice can hardly conceive of the enormous torques involved. Some idea of the stresses involved can be obtained by considering the fact that 28 and 30-inch shafts have been twisted off by the torsional strains. The other alternative is to put a weak link in the chain, that is to purposely weaken some particular section so that it will fail under heavy overload.

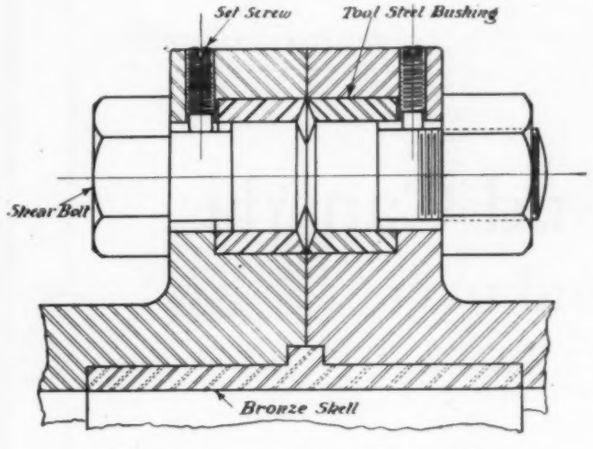

FIG. 2.—*Detail of shear bolt assembly.*

The breaking point is usually built into one of the spindles. This is not a new idea, in fact it has been used for many years. In a large number of instances, however, the results have been disastrous. The design has been such that the spindle in breaking often set up thrusts and raised Cain in general when it broke. The parts involved were usually expensive and the average designs were such that the breaking of the spindle meant from one to two hours delay. The thrusts and the consequent damage was usually caused by failure to hold the broken ends of the spindle and as a result they rode each other.

There has been recently installed on the 84-in. plate mill at the Brier Hill Department of the Youngstown Sheet & Tube Company, a spindle which appears to have eliminated practically all of the difficulties heretofore encountered. This drive is a 2,500 hp., 235 rpm. motor driving an 84-in., 3-high plate mill. The motor is connected through a flexible coupling to a heavy fly wheel which in turn is connected to the pinion of the Kennedy stand by the combination flexible coupling and breaking spindle illustrated. Six shear bolts are provided as shown on the detailed sketch. The shear bolts are shouldered and are prevented from flying around the mill after breaking by set screws as shown. After breaking, the shear bolts are free to move back some distance. The shear bolt holes are bushed with hardened tool steel bushings. If the break in the bolt should be ragged the tool steel bushings will promptly shear off the ragged edge. A very important feature of the design is the means provided for holding the two halves of the center member after breaking. A heavy bronze shell is inserted inside the center member and held central by a flange which rests in a recess in the two halves of the center member casting. After the shear bolts have broken the two halves of the center member are held firmly in line by this bronze shell. In case of a bad cobble or wrapper in the mill the bolts would shear and the mill half of the coupling would stop dead while the fly wheel end would be free to revolve with the fly wheel and the motor. This drive has been thoroughly tried out. The required section of bolt is largely a matter of cut and try. In determining this section the bolts were sheared repeatedly and the performance was entirely satisfactory in every respect. At no time has there been any evidence of a thrust or disturbance of any kind. The shear bolts are of ordinary soft machine steel and can be quickly and easily replaced at a small expense. Before the installation of this spindle the mill had broken its leading spindle at very frequent intervals. The cost of replacing a leading spindle was approximately $1,000, and the delays encountered were also expensive. We believe that we have solved the problem on this particular mill and are sure that a properly designed breaking spindle will in almost every case aid the mechanical engineer in protecting his mill machinery against shock loads. By use of the properly designed breaking spindle the mechanical engineer has a mechanical fuse which approaches in efficiency and simplicity the refillable fuse employed by the electrical engineer.

Designs New Transformer Cases

A news item of more or less interest to our readers is theannouncement of the Packard Electric Company, Warren, O., to the effect that the designing of a complete new line of steel cases for distribution transformers has been completed. The use of cast-iron cases by this company has been discontinued, and all shipments are being made in the new cases.

In addition to a complete line of distribution transformers in accordance with the standards of the Electric Power Clubs, the Packard Electric Company, manufactures power transformers up to a capacity of 10,000 kva. and a complete line of Weaherproof Metering Transformers, both in the form of individual units, and also with both units contained in the same oil-filled case. The new steel cases will also be used in connection with Packard A W Regulators.

Your JANUARY ISSUE

will contain a complete
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Main Roll Drives Installed

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of 300 h.p. and over

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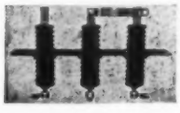
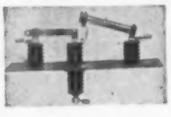
THE STANDARD OF COMPARISON

The Delta Star

UNIT TYPE





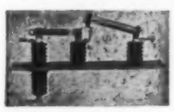
Responsibility of Standardization

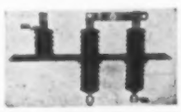
DURING the last few years we have been repeatedly impressed with the fact that standardization carries with it a responsibility of which we were not fully aware, when some twelve years ago, we embarked upon our now well-known venture of creating order and scientific proportions out of the chaos existing in the high tension equipment field.

We knew that standardization should involve only essentials that are not changed by the fickles of fashion nor by natural development along scientific lines of the particular part in question. By way of illustration, when our creators of Unit Type standardized on outdoor insulator units, they did not select any particular make, shape or style of insulator body. Instead of being guided by such a *changeable* quantity as porcelain design, they went clear back to Euclid and standardized on a *dimension* — the distance from top of cap to bottom of pin. In a similar way, the distance between insulators on switching equipment were determined — not by the appearance of any particular make of insulator—but by a *definite relation* which we discovered should be maintained between an adopted flashover value of insulator and a safe air gap separation.

Our contemporaries have produced an abundance of printed evidence to convince us that Delta-Star is now an acknowledged "STANDARD OF COMPARISON." Much as this elates us, it nevertheless creates a feeling of unwished for responsibility, for to associate certain dimensions with certain operating voltages may not result in safe construction unless one knows the *facts* behind the figures—any more than a cemented switch insulator would be a desirable product *unless* mechanical and electrical features are properly balanced and the cement mixed with brains.

Responsibility of Standardization





Would YOU Like a Catalog?

DELTA-STAR ELECTRIC CO.

2400 Block Fulton St Chicago, Illinois

Albany, N. Y., 715 City Savings Bank Bldg.
Birmingham, Ala., 827-830 Brown-Marx Bldg.
Boston, Mass., 294 Washington St.
Buffalo, N. Y., 595 Ellicott Square
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Columbus, Ohio, 600 Joyce Realty Bldg.
Detroit, Mich., 708 Ford Bldg.
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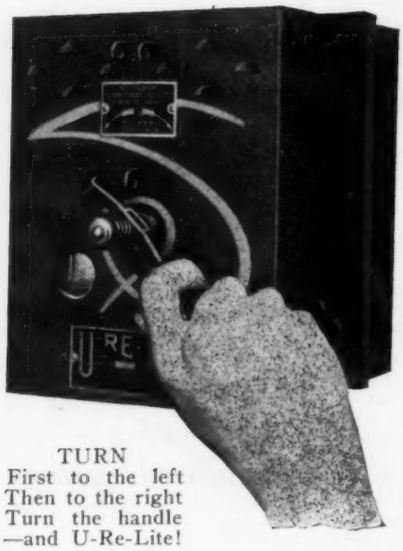
UNIT TYPE CEMENTED SWITCH INSULATORS

PROTECTION

for your electrical equipment



TURN
First to the left
Then to the right
Turn the handle
—and U-Re-Lite!

Safeguarding electric motors, power and lighting circuits, against overloads and "shorts" is of such prime importance that only the best protection is good enough. Inadequate protection may mean a fire or the destruction of costly equipment.

U-RE-LITE

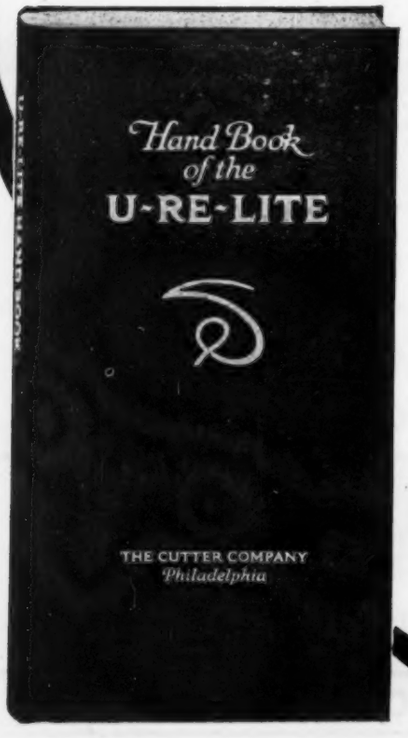
has for over five years given to industry this vital protection.

"The I-T-E Circuit Breaker in the Steel Box"

possesses a certainty of operation which puts it in a class by itself. When an overload or "short" occurs in a circuit protected by a U-RE-LITE, it merely opens the line. To restore service, simply turn the handle on the FRONT of the box

First to the left, then to the right,
Turn the handle, and U-RE-LITE!

Service is then resumed immediately, and what is even more important, this is accomplished without calling the electrician.
YOU DO IT—YOU U-RE-LITE!

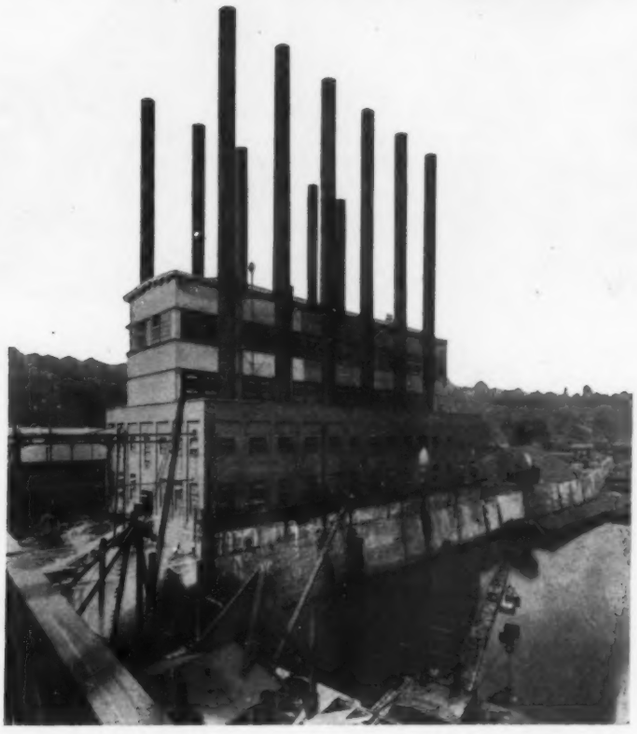


Write for 96-Page Illustrated Catalog—HAND BOOK OF THE U-RE-LITE. Sent free upon request.

The CUTTER COMPANY
ESTABLISHED 1888 I-T-E PHILADELPHIA

1826 Hamilton Street

LADD
WATER TUBE BOILERS



NO matter what your local conditions of size, space, fuel burning equipment or other limitations may be, there's a specially designed type of LADD WATER TUBE BOILER to meet your requirements.

LADD BOILERS have been built varying from 25 H.P. to 120 H.P. per foot of furnace width, and may be operated with any type of modern stoker equipment, with Blast Furnace or Natural Gas, with Powdered Coal or various combinations of these fuels.

The simple yet rugged construction and design—which makes every part of the boiler easily accessible—the rapid, unrestricted circulation and properly designed and proportioned gas passages makes the LADD BOILER perform its functions in a satisfactory, highly efficient and workmanlike manner. Our installations are our best talking points.

Write for our latest bulletin.

THE GEORGE T. LADD COMPANY

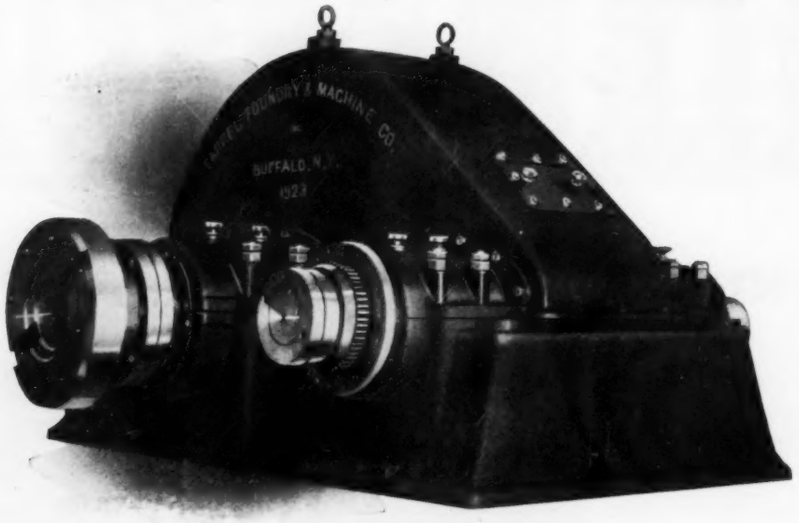
First National Bank Building
PITTSBURGH, PENNA.

CHICAGO OFFICE
528 McCormick Building

PHILADELPHIA OFFICE
502 Franklin Bank Building

NEW YORK OFFICE
39 Cortland Street

WATER TUBE BOILER LADD

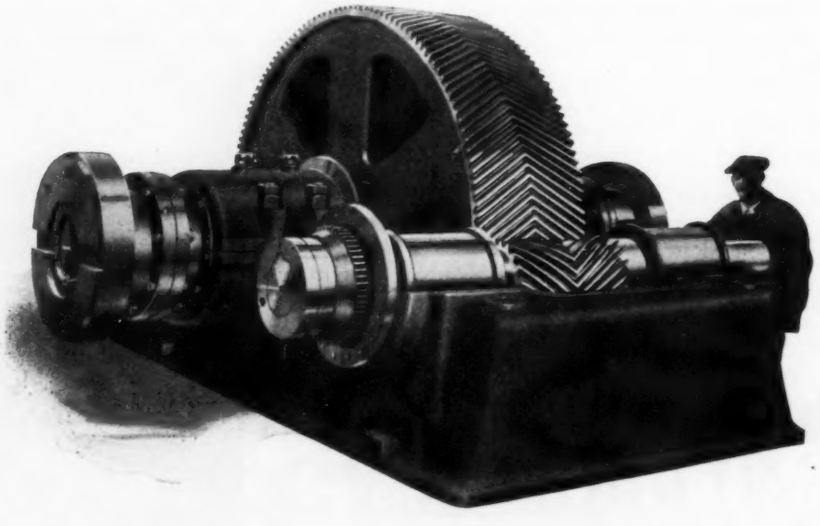


FARREL ROLLING MILL DRIVE

THE STRONGEST — MOST COMPACT AND EFFICIENT DRIVE
ON THE MARKET

SYKES HERRINGBONE GEARS

NO GAP AT THE CENTER — SHARP APICES

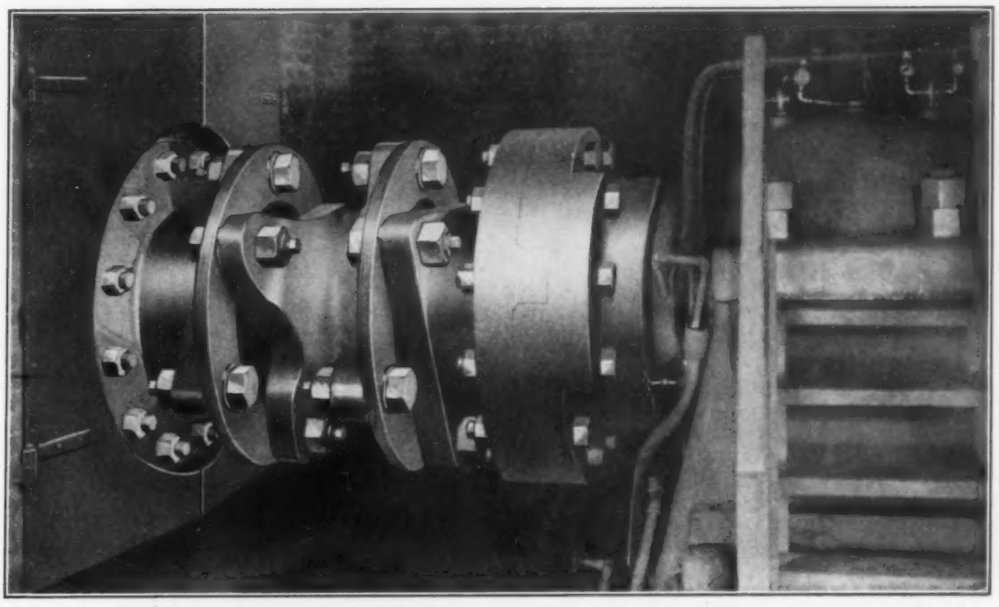


FARREL FOUNDRY & MACHINE CO.

BUFFALO, N. Y., U. S. A.

THOMAS FLEXIBLE COUPLINGS

FOR MAIN ROLL DRIVES



Thomas Mill Type Coupling on 84″ Plate Mill, 2500 H.P., 235 R.P.M.
Youngstown Sheet & Tube Company

Above coupling and another on the 5,000 H.P. 197 R.P.M. 132″ plate mill drive at this same plant have operated a total of six years with absolutely no maintenance charge.

No sliding or wearing parts
No loosely connected members
No frictional resistance to end float
No lubrication
Three very accessible bolts, removal of which frees either end of drive

The Thomas coupling is the only mill spindle which has these features. The first two are the most important, as a "tight" drive eliminates all backlash and prevents the hammering action, which is so destructive to gears, bearings and shafts. The net result is an immediate reduction in maintenance costs.

Thomas Flexible Coupling Co., Warren, Pa.

SALES OFFICES: Pittsburgh Chicago Cleveland Philadelphia Boston St. Louis New York Springfield

INDUSTRIES using electrical energy save 80% annually in fuse maintenance costs by installing Economy Renewable Fuses in the place of "one-time" fuses.

The famous Economy "Drop Out" Renewal Link—the least expensive and the only portion of the fuse destroyed in operation—makes this saving possible.

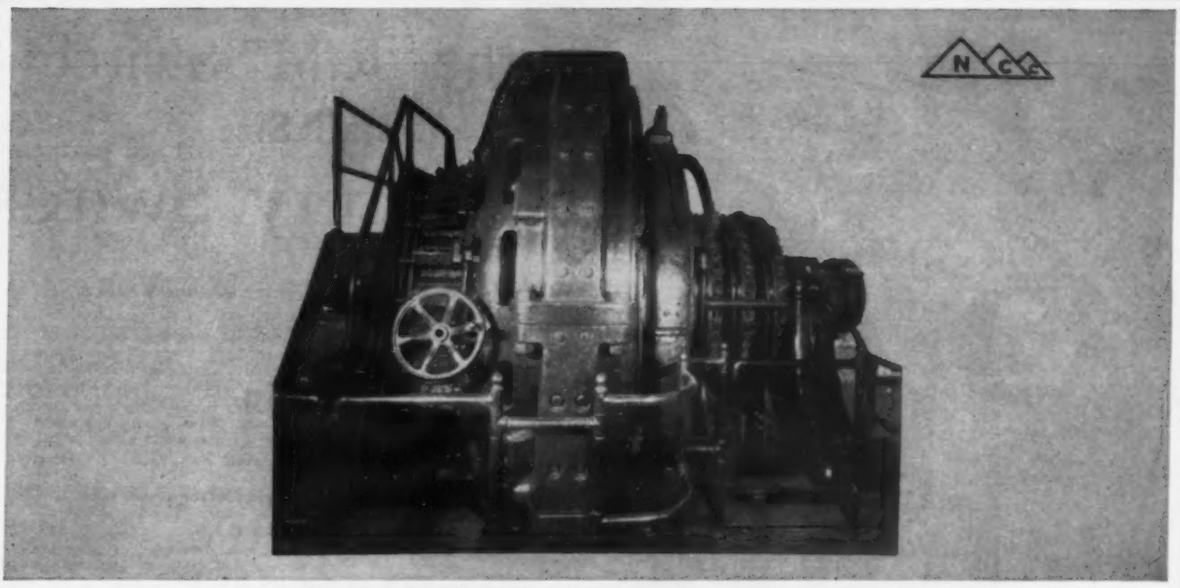
Check up your fuse costs.

For Sale by All Leading Electrical Jobbers and Dealers

ECONOMY FUSE & MFG. COMPANY
Chicago, U. S. A.

Economy Fuses were the first line using an inexpensive bare renewal link for restoring a blown fuse to its original efficency to be Approved in All Capacities by the Underwriters' Laboratories.

ECONOMY *renewable* FUSES



259

SUPREME on the DC side of rotary converters—NCC 259. This remarkable brush, developed by the Union Carbide & Carbon Research Laboratories, gives minimum commutator wear. It does not burn the commutator, and it minimizes the possibility of flashovers. It is quiet in operation even on large converters with high peripheral speeds, and its life is commensurate with the service.

In two years since its general introduction it has become the most successful and most talked-of brush for rotary converter service.

Ringsdorff ET-10

COOLER ring temperatures and higher operating efficiency are secured by using the famous Ringsdorff ET-10 on the AC side of rotary converters. This brush has lower contact losses—that's why machines fitted with it run cooler and more efficiently. It is comparatively free from dusting. This is indicated by the lessened wear of both rings and brushes.

These marked advantages in operation and the longer life of Ringsdorff ET-10 make it an economical brush even at its somewhat higher price.

National Pyramid Brushes

Manufactured and guaranteed by

NATIONAL CARBON CO., INC., Cleveland, Ohio—San Francisco, Cal.

Canadian National Carbon Co., Limited, Toronto, Ontario

Emergency Service Plants

CHICAGO, ILL.
551 West Monroe St.
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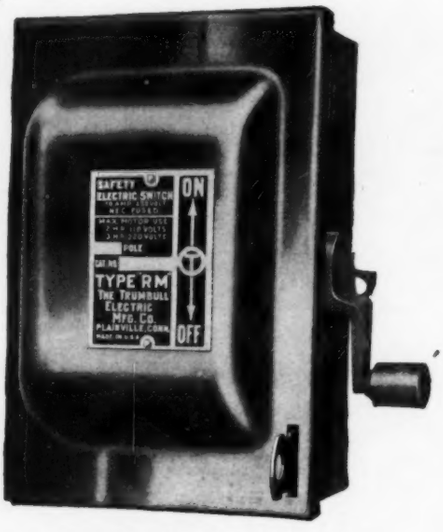
Just the Switch for use with small motors in steel mills or for use on lighting circuits.

—the "R.M" Switch

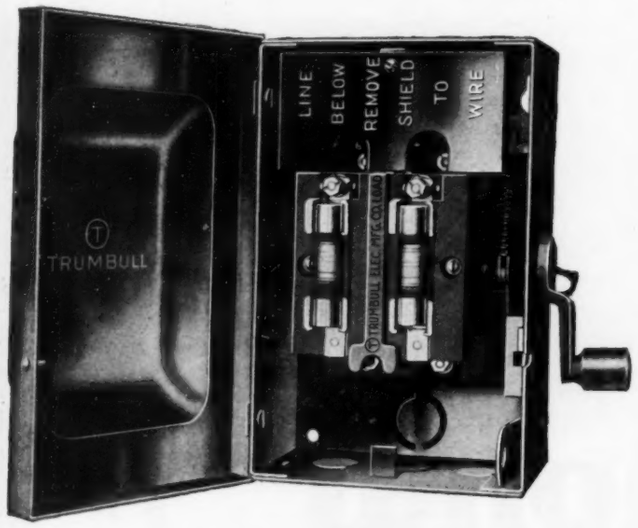
Small Size

Full Safety Switch

30 Amperes—250 Volts



Box Closed—8" x 5¼" x 4½"



Box open. Fusible
Fuse block and shield are reversible

1. The Switch box is very compact (2 Pole 4½ x 8", 3 Pole 6¾" x 8"), meeting a long-felt need for a rugged, full safety article for installation where size is a prime factor.
2. Removing two screws enables entire Switch and fuse block to be takes from box. Thus, entire box space is available for connecting conduit and running wires.
3. Quick make and quick break with Type "A" interlock.
4. Handle operates a compression spring on same principle as rest of Type "A" line. Handle would operate Switch if spring should fail.
5. Constructed on double break principle. Blades are carried by a rotor of moulded material, actuated by the cam of the Q.M. and Q.B. mechanism.
6. When blades are in "off" position they throw into deep narrow slots in the base and thus effectually snuff out any arc which might have a tendency to follow.
7. The Switch base, fuse block base, and rotor are all of high grade moulded material of unusual strength, and will stand much abuse in handling.
8. The fuse block mounted over the Switch base, brings fuses directly to the front in most accessible position. Dead front construction.
9. Line terminals on Switch base are accessible without removing fuse block. Load terminals are on fuse block above the line terminals. Thus on fusible Switches, both line and load terminals are on same end of box.
10. By reversing position of fuse block, line and load connections can be made at the bottom of Switch if desired. We regularly furnish the Switch top connected.
11. A shield attached by one screw covers line terminals, preventing any possible contact with live parts. This shield will fit only on terminal end, top or bottom, depending on position of fuse block.
12. Switches furnished fusible or no fuse. On no-fuse Switch the fuse block is omitted and line can be connected at either top or bottom, as desired.
13. This Switch gives the trade a very high grade article. Quick make and quick break, with full safety features, at an exceedingly low price.
14. 440, 50 volts Switches. 2 and 3 Pole will shortly be placed on the market.
15. Handle is a ribbed steel punching with cast iron knob—practically indestructible.

NO FUSE 250				FUSIBLE 250 V.			
Cat. No.	Pole	Volt	List Each	Cat. No.	Pole	Volt	List Each
46221	2	250	$4.80	92221	2	250	$5.50
46321	3	250	6.00	92321	3	250	7.00
46421	4	250	8.50	92421	4	250	9.50

We can furnish 3 p. fusible switches with solid neutral at regular price on request.

Discount Trumbull Schedule C

You can get all the details of the complete Trumbull Line by asking your jobber for Bulletin No. 5.

The Trumbull Electric Mfg. Co.

Plainville, Conn.

New York 114 Liberty St. | Boston | Chicago 2001 W. Pershing Road | Atlanta, Ga. | Philadelphia | San Francisco 595 Mission St.

Unloads Pig or Scrap Iron much cheaper than the steam-cranes.

The P & H can be moved readily.

Can do work that could not be accomplished at all with cranes on tracks.

10

INDUSTRIAL HANDLING *September, 1924*

Tractor Crane Repays Cost in Year

By P. W. Reck

Master Mechanic, The Bettendorf Company, Bettendorf, Iowa

THIS company has derived a great deal of satisfaction from the installation, some time ago, of a "crawler" type of tractor crane, a machine which propels itself over any kind of footing, regardless of obstacles like an army "tank."

We have been using this piece of equipment on the difficult job of excavating ground for a tunnel 7 by 7 ft. and about 900 ft long, to be used for power transmission lines. In this work alone we estimate that the crane paid one-half of its cost in the first six months of use.

As we also have and use three 15-ton steam cranes of the locomotive type, we are able to make some interesting performance comparisons. We find that we can unload pig or scrap iron much cheaper with the tractor crane than with the steam machines. The tractor outfit can readily be moved to either side of a car, completely unloading it in short order, whereas the steam cranes have to get first on one end of the car and then on the other because their booms are not full car length.

The fact that the tractor crane can be used anywhere in or about the plant, track or no track, is also a great advantage, as work can thus be done that could not be accomplished at all with track cranes.

The Bettendorf Company's crawler-type tractor crane, which repaid half its cost in six months on excavating work alone. It is seen here handling pig iron with a lifting magnet.

The P & H is driven by gasoline or electric motor. It is ready for work at a moment's notice — and when not needed — whether for 30 minutes or 3 hours it can be as readily shut down. No fuel is wasted.

The operator has instant control of crane travel, hoisting and swing through a full circle. He can locate his P & H at either side or end of cars or material stock piles. Like P & H Electric Traveling Cranes and Hoists, P & H Corduroy Cranes provide dependable, economical service with low maintenance costs.

Let us mail our Bulletin 40-X to you.

Excavating Machinery Division

Established 1884

PAWLING & HARNISCHFEGER CO.

3855 National Ave., Milwaukee, Wis.

New York, Atlanta, Detroit, Kansas City, Chicago, Portland, Memphis, Dallas, Seattle, Philadelphia, Pittsburgh, Los Angeles, San Francisco

Warehouses and Service Stations:
New York, Memphis, San Francisco

P&H CORDUROY CRANES

Type S

The Disconnecting Switch That Never Fails

Liberal Design
Conservative Rating
Sturdy Construction
} **Spell—Reliable Operation**

These characteristics of the Type S line of disconnecting switches have been confirmed by exhaustive tests and proved by actual service records in the largest and most important generating stations.

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Pa.

Sales Offices in All Principal Cities of the United States and Foreign Countries

Westinghouse

Some Characteristics of the Type CW Motor

The Frame
Cast steel, of exceptionally sturdy construction. Feet are cast integrally with frame in all but the smaller sizes which have riveted forged steel feet.

The Rotor
Of sturdy construction. Especially adapted to severe service. For 25 hp. and below cores are made of steel laminations bolted or rivetted into a unit which is mounted on a shaft. For larger types, laminations are mounted on a cast iron spider which is pressed on the shaft and keyed.

The Stator
The same careful design, workmanship, and selection of materials used in the rotor are embodied in the stator. Snug-fitting, well braced coils insure utmost sturdiness.

The Shaft
Made of axle steel ot rigid specifications. Will not twist nor spring when subjected to high torques. Can be pressed out without disturbing core and windings.

The Ventilation
Design of motor insures uniform temperature and prevents hot spots and air pockets. Fans on rotor keep air in constant motion.

For Constant or Varying Speed Service

WESTINGHOUSE Type CW wound rotor induction motors are designed for constant or varying speed duty. They are especially suitable for steel mills where a motor with a high starting torque is required.

The Type CW motor is used throughout the steel industry for belted, coupled, and geared service.

Have Westinghouse engineers assist in the selection of electrical equipment for your plant.

Westinghouse Electric & Manufacturing Company
East Pittsburgh Pennsylvania
Sales Offices in All Principal Cities of
the United States and Foreign Countries

Westinghouse

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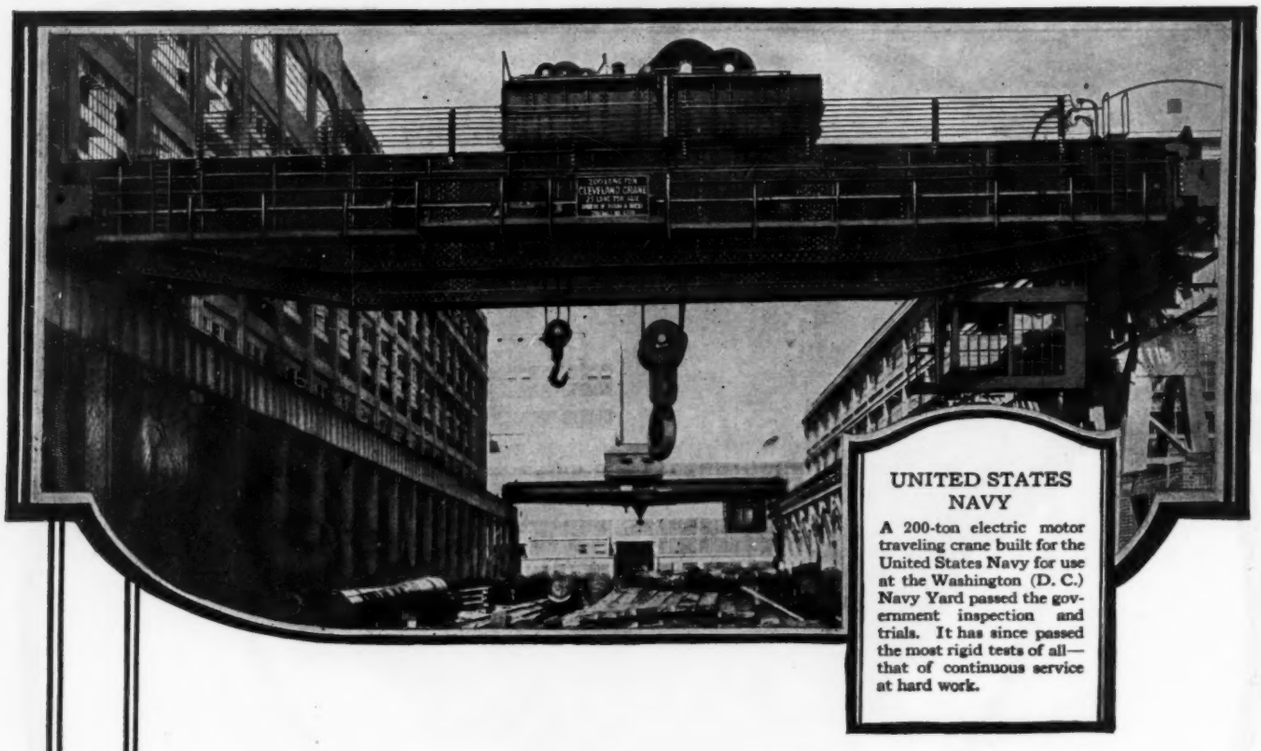


UNITED STATES NAVY

A 200-ton electric motor traveling crane built for the United States Navy for use at the Washington (D. C.) Navy Yard passed the government inspection and trials. It has since passed the most rigid tests of all—that of continuous service at hard work.

Your Specifications or Ours

The right crane for the job—that is the most important objective before our engineers when designing a new Cleveland Crane. And there is no deviation from that rule, whether the crane is built to your specifications or our own.

The same interest in building "the right crane" is shown in every estimate submitted, from the smallest 5-ton shop crane to a 500-ton gantry, built to withstand the most severe service imaginable.

THE CLEVELAND CRANE & ENGINEERING CO.

New York City
30 Church Street

WICKLIFFE, OHIO.

Pittsburgh
511 Farmers' Bank Bldg.

CLEVELAND CRANES

Made in
2 and 3 Pole

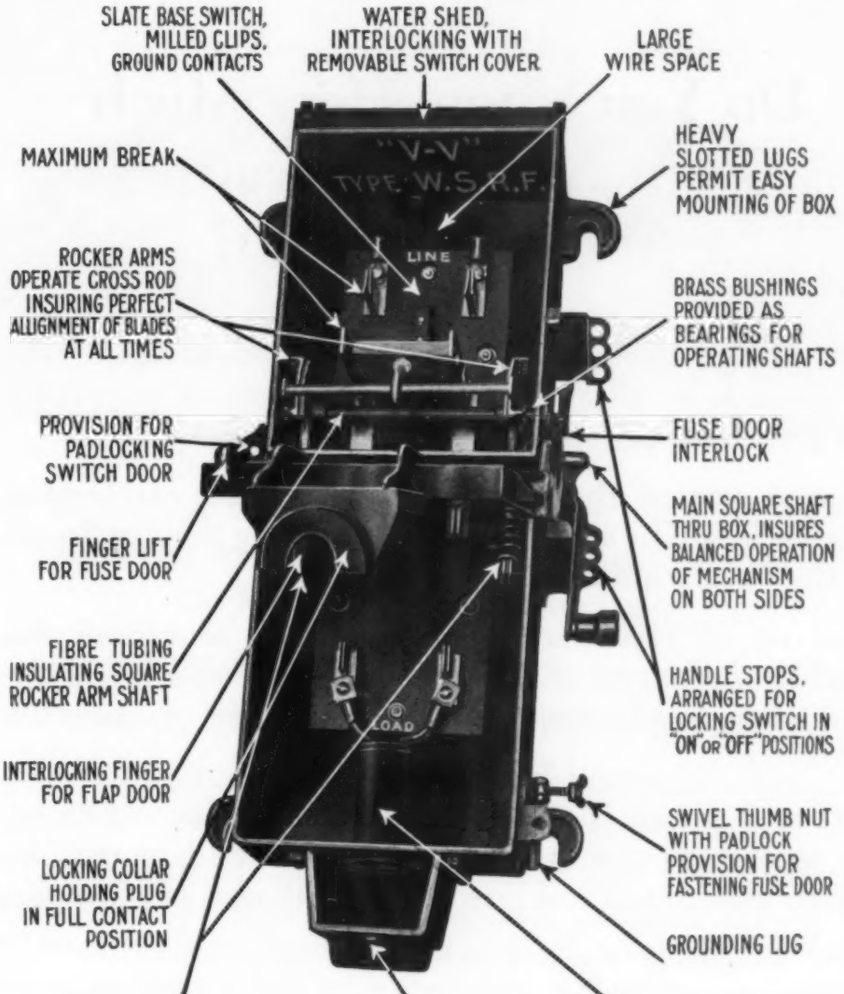
"V. V."

100 and 200 Ampere
250, 500 and 600 Volt

TYPE WSRF

QUICK MAKE and QUICK BREAK SAFETY SWITCH and RECEPTACLE

Cast Iron Weather Proof

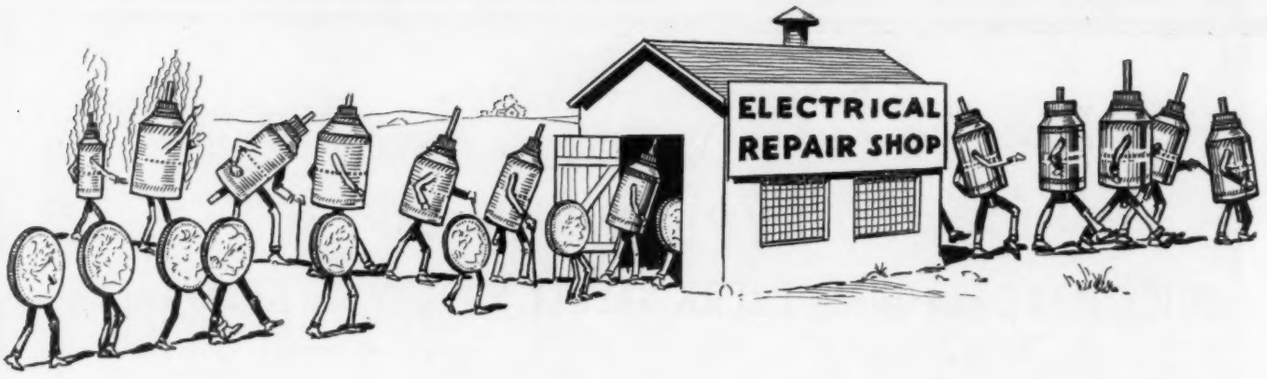

SLATE BASE SWITCH, MILLED CLIPS, GROUND CONTACTS
WATER SHED, INTERLOCKING WITH REMOVABLE SWITCH COVER
LARGE WIRE SPACE
HEAVY SLOTTED LUGS PERMIT EASY MOUNTING OF BOX
MAXIMUM BREAK
ROCKER ARMS OPERATE CROSS ROD INSURING PERFECT ALLIGNMENT OF BLADES AT ALL TIMES
BRASS BUSHINGS PROVIDED AS BEARINGS FOR OPERATING SHAFTS
PROVISION FOR PADLOCKING SWITCH DOOR
FUSE DOOR INTERLOCK
FINGER LIFT FOR FUSE DOOR
MAIN SQUARE SHAFT THRU BOX, INSURES BALANCED OPERATION OF MECHANISM ON BOTH SIDES
FIBRE TUBING INSULATING SQUARE ROCKER ARM SHAFT
HANDLE STOPS, ARRANGED FOR LOCKING SWITCH IN "ON" OR "OFF" POSITIONS
INTERLOCKING FINGER FOR FLAP DOOR
SWIVEL THUMB NUT WITH PADLOCK PROVISION FOR FASTENING FUSE DOOR
LOCKING COLLAR HOLDING PLUG IN FULL CONTACT POSITION
GROUNDING LUG
SPRING TOGGLES INSURE POSITIVE QUICK MAKE AND WIDE QUICK BREAK
SPRING CLOSING FLAP COVER INTERLOCKED WITH FUSE DOOR, PREVENTS ACCESS TO LIVE PARTS
STEEL ENCASED RECEPTACLE
"V-V"
TYPE W.S.R.F.
LINE
LOAD

V. V. FITTINGS COMPANY

PHILADELPHIA
U. S. A.

New York Office—50 Church Street
Pittsburgh Representative—
P. H. Schaum, 933 Liberty Ave.

Chicago Office & Warehouse—710 W. Jackson Blvd.
Cleveland Representative—
S. R. Shepard, 1240 Ontario Street



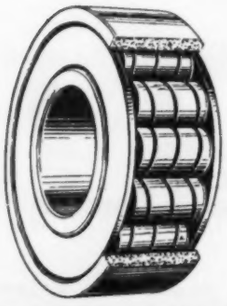
Do You Know How Much Worn Armature Bearings Are Costing You?

IF average steel plant conditions exist in your mill, there is an almost continuous stream of armatures going to your electrical shop for repairs.

A large part of these are rewindings and mechanical repairs caused by worn bearings dropping the armatures on the field windings.

The use of Hyatt roller bearings will eliminate this trouble and expense. By reducing wear to a negligible item they hold armature shafts in true position indefinitely.

Part of your job is to reduce operating costs. Look up the answer to our question and then write to us. We will be glad to tell you how little it will cost to eliminate this big item.



HYATT ROLLER BEARING COMPANY
NEWARK, NEW JERSEY

HYATT ROLLER BEARINGS FOR ELECTRIC MOTORS

Dust-Tight Heavy Duty Unit

For Steel Mills and Foundries

A Dust Tight Glass Cover Sealed to 14" R.L.M. Type RR Reflector by a Rugged Gasketed Cast Holder

Catalog No. 29950 For Cover Only

Hinged to permit easy change of lamps.

Made heavy and tight to keep out Dusts, Vapors and Smoke.

Cuts down labor for maintenance and keeps illumination up to original high values.

This device is an indication of the extent to which Benjamin is developing from time to time special protective equipment designed to maintain illumination at original standard without excessive expense for labor in cleaning reflectors and replacing broken lamps.

The Benjamin line of lighting equipment includes all sorts of heavy duty reflectors and fixtures designed to meet both usual and unusual lighting requirements in shops, mills and foundries.

Any office will gladly furnish specific information.

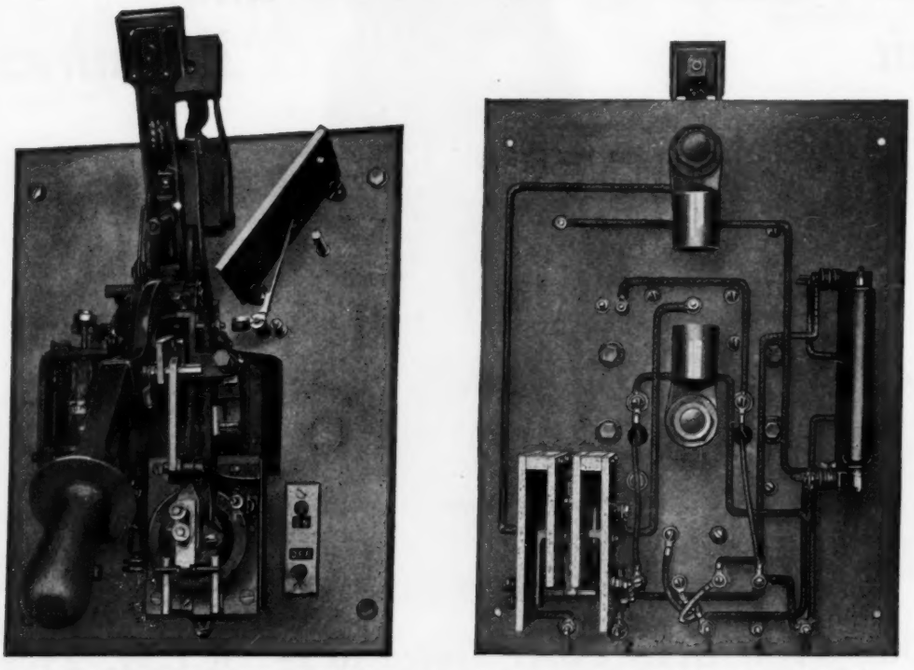
Benjamin Electric Mfg. Co.

NEW YORK
247 W. 17th Street

CHICAGO
120-128 S. Sangamon Street

SAN FRANCISCO
448 Bryant Street

A Manually Operated Circuit Breaker
That Recloses Automatically



Front and Rear Views, Type "AHM" 600-Ampere Automatic Reclosing Circuit Breaker
With Removable Handle for Manual Operation

or

An Automatic Reclosing Circuit Breaker
That May Be Operated Manually

either way

This Circuit Breaker Embodies All That Is to Be Had in a Circuit Breaker
and Assures You High Grade Circuit Breaker Protection
At All Times and Under All Conditions

With That Refinement in Service That Can Be Had Only With

The Circuit Breaker with Brains

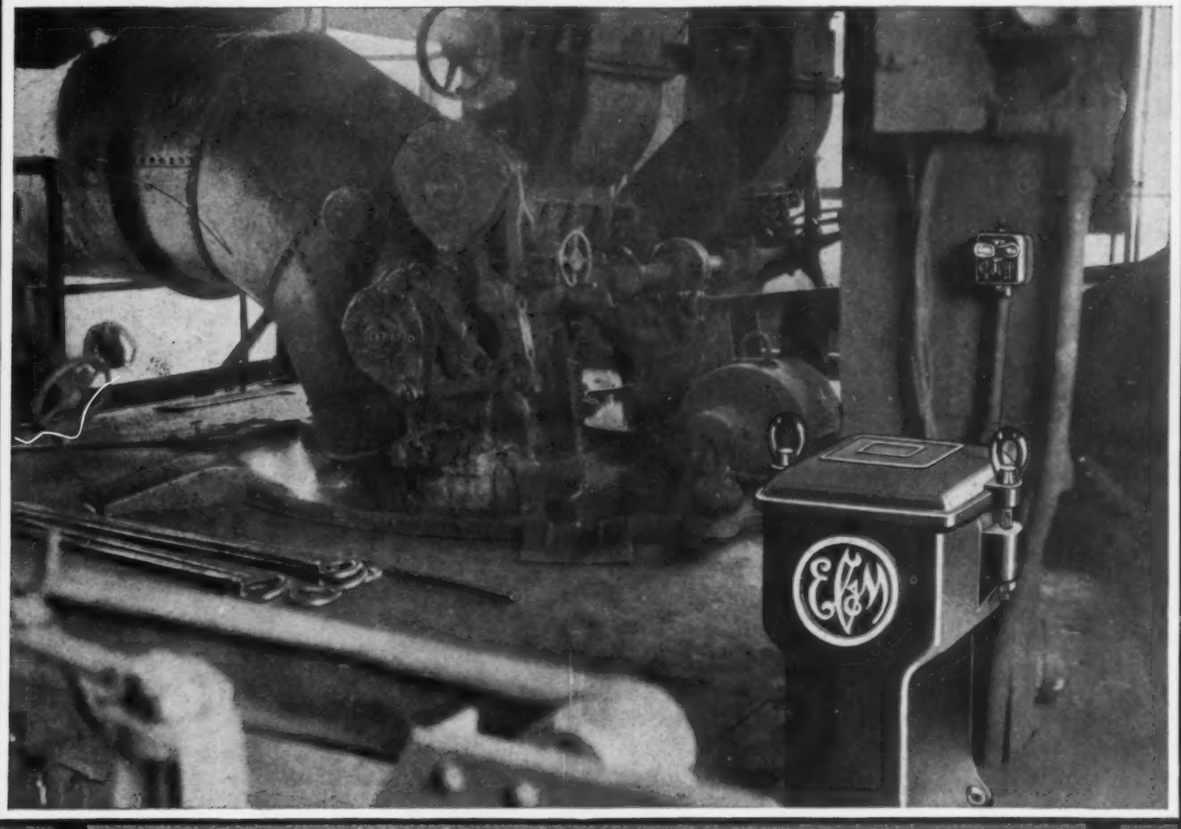
Bulletin 314-F Gives Details.

THE AUTOMATIC RECLOSING CIRCUIT BREAKER CO.

COLUMBUS, OHIO

PITTSBURGH: 1815 Oliver Bldg.
ST. LOUIS: 401 National Bank of Commerce Bldg.
WILKES-BARRE, PA.: 816 Miners Bank Bldg.
CHARLESTON, W. VA.: 314 Moore Building

FUME-PROOF



This EC&M Automatic Compensator is still working after four years with no trouble of any kind.

Think of what it has been through. It operates a motor driving a gas producer and gases are in the air all the time.

It is located outdoors and gets 100° weather in the summer and zero weather in the winter.

It has been rained on and it has been snowed on.

Yet it is still working after four years without a failure.

EC&M Automatic Compensators can be supplied for any voltage up to 2300 volts.

Write for Bulletin 1042-D

THE ELECTRIC CONTROLLER & MFG. CO.

CLEVELAND, OHIO

BIRMINGHAM - BROWN-MARX BLDG.
CHICAGO - CONWAY BLDG.
CINCINNATI - 1ST NATIONAL BANK BLDG.
DENVER - 3535 WALNUT ST.
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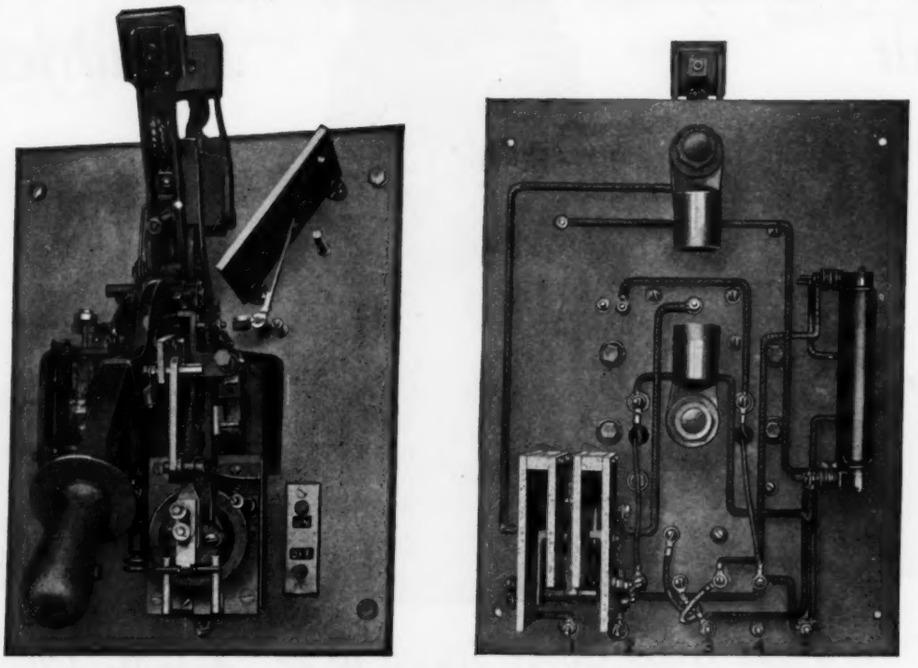
LOS ANGELES - THOMAS MACHINERY CO. AMERICAN BANK BLDG.
NEW YORK - 50 CHURCH ST.
PHILADELPHIA - WITHERSPOON BLDG.
PITTSBURGH - OLIVER BLDG.
SAN FRANCISCO - CALL BUILDING
SEATTLE - 524 1ST AVE. SOUTH
TORONTO - TRADERS BANK BLDG.

A Manually Operated Circuit Breaker
That Recloses Automatically



Front and Rear Views, Type "AHM" 600-Ampere Automatic Reclosing Circuit Breaker
With Removable Handle for Manual Operation

or

An Automatic Reclosing Circuit Breaker
That May Be Operated Manually

either way

This Circuit Breaker Embodies All That Is to Be Had in a Circuit Breaker
and Assures You High Grade Circuit Breaker Protection
At All Times and Under All Conditions

With That Refinement in Service That Can Be Had Only With

The Circuit Breaker with Brains

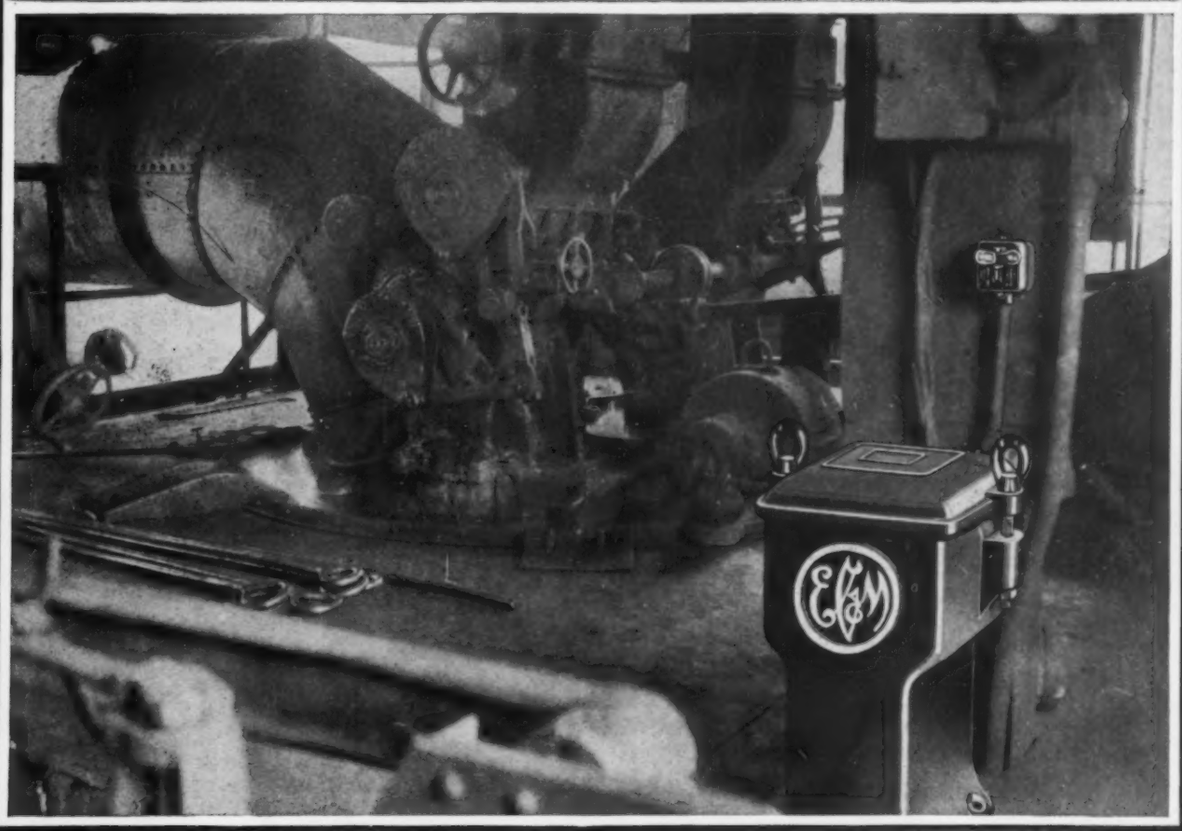
Bulletin 314-F Gives Details.

THE AUTOMATIC RECLOSING CIRCUIT BREAKER CO.

COLUMBUS, OHIO

PITTSBURGH: 1815 Oliver Bldg.
ST. LOUIS: 401 National Bank of Commerce Bldg.
WILKES-BARRE, PA.: 816 Miners Bank Bldg.
CHARLESTON, W. VA.: 314 Moore Building

FUME-PROOF



This EC&M Automatic Compensator is still working after four years with no trouble of any kind.

Think of what it has been through. It operates a motor driving a gas producer and gases are in the air all the time.

It is located outdoors and gets 100° weather in the summer and zero weather in the winter.

It has been rained on and it has been snowed on.

Yet it is still working after four years without a failure.

EC&M Automatic Compensators can be supplied for any voltage up to 2300 volts.

Write for Bulletin 1042-D

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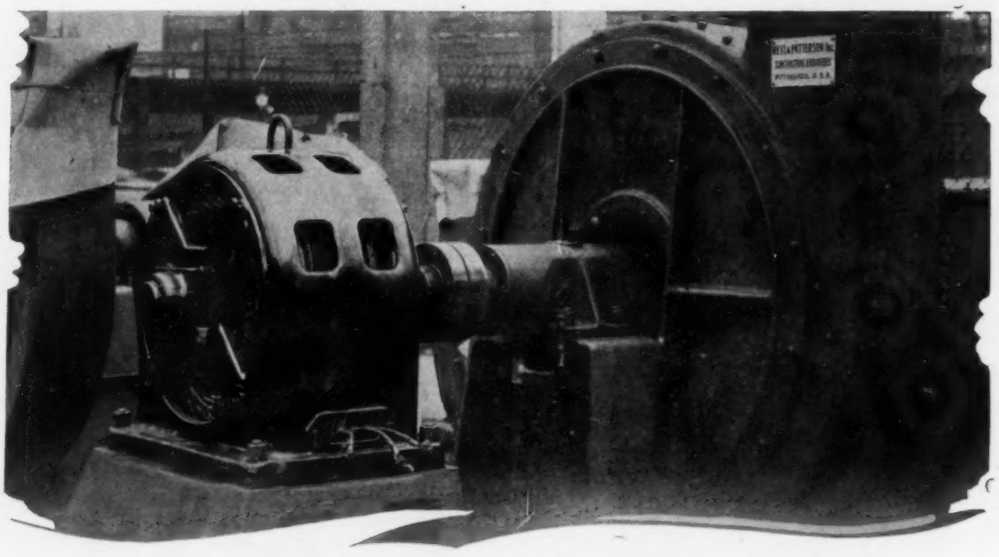
SKF



Going Strong for Six Years

Ball Bearing Motors on Coal Feed Fans

LITTLE work for the motor repair man with the type of electrically driven powdered coal feed fans shown above. Some of them have been on the "go" over six years and are still giving reliable service.

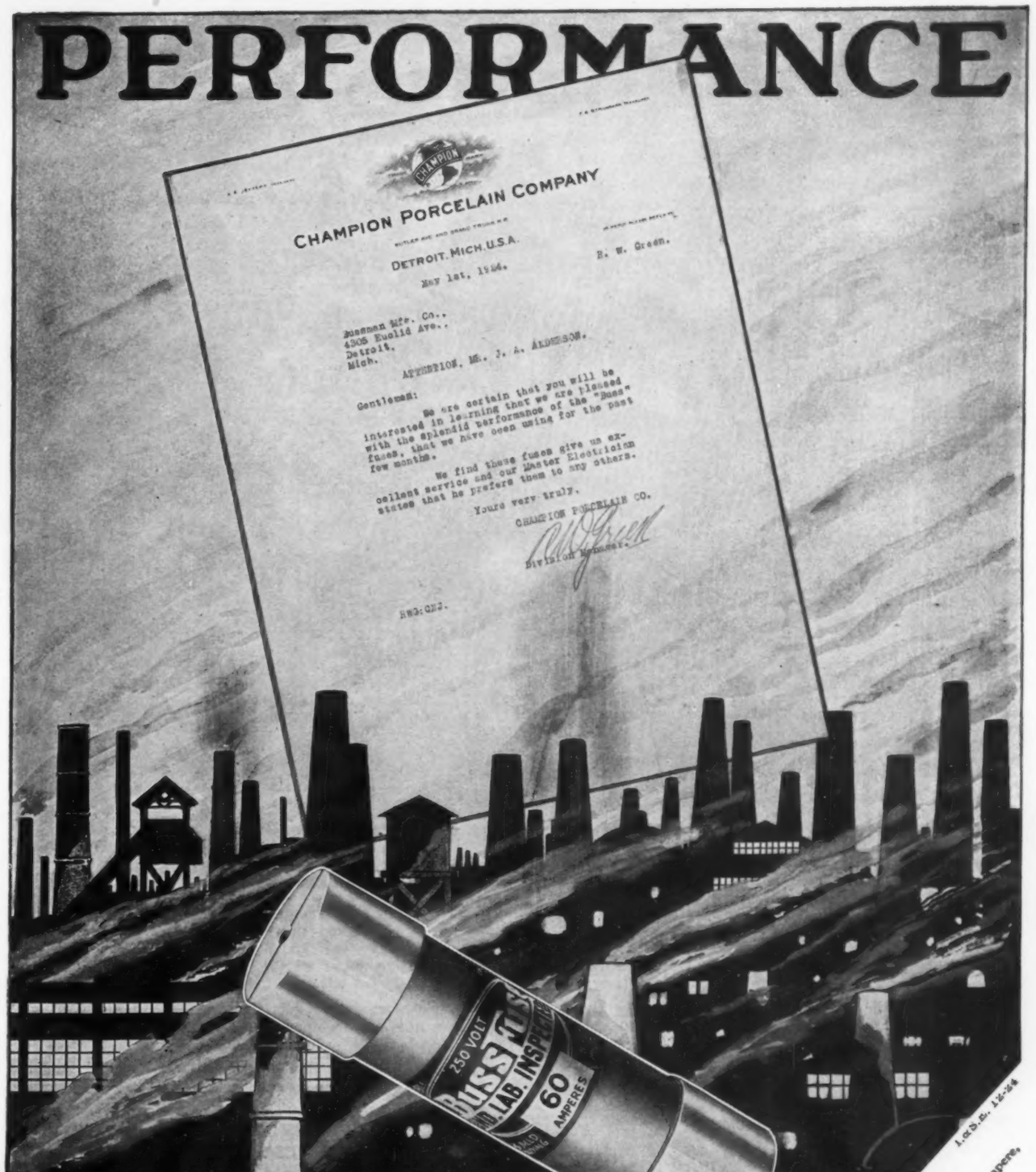
The high precision and inherent long life of Skayef Self-Aligning Ball Bearings are a positive assurance of low cost and trouble-free operation.

THE SKAYEF BALL BEARING COMPANY

Supervised by SKF INDUSTRIES, INC., 165 Broadway, New York City

1289

PERFORMANCE


CHAMPION PORCELAIN COMPANY
DETROIT, MICH. U.S.A.
May 1st, 1924.
R. W. Green.
Bussman Mfg. Co.,
4305 Euclid Ave.,
Detroit,
Mich.
ATTENTION, MR. J. A. ALDERSON.
Gentlemen:
We are certain that you will be interested in learning that we are pleased with the splendid performance of the "Buss" fuses, that we have been using for the past few months.
We find these fuses give us excellent service and our Master Electrician states that he prefers them to any others.
Yours very truly,
CHAMPION PORCELAIN CO.
Division Manager.
RWG:GMJ.
250 VOLT
BUSS FUSE
60
AMPERES

BUSS FUSES

APPROVED IN ALL TYPES AND SIZES

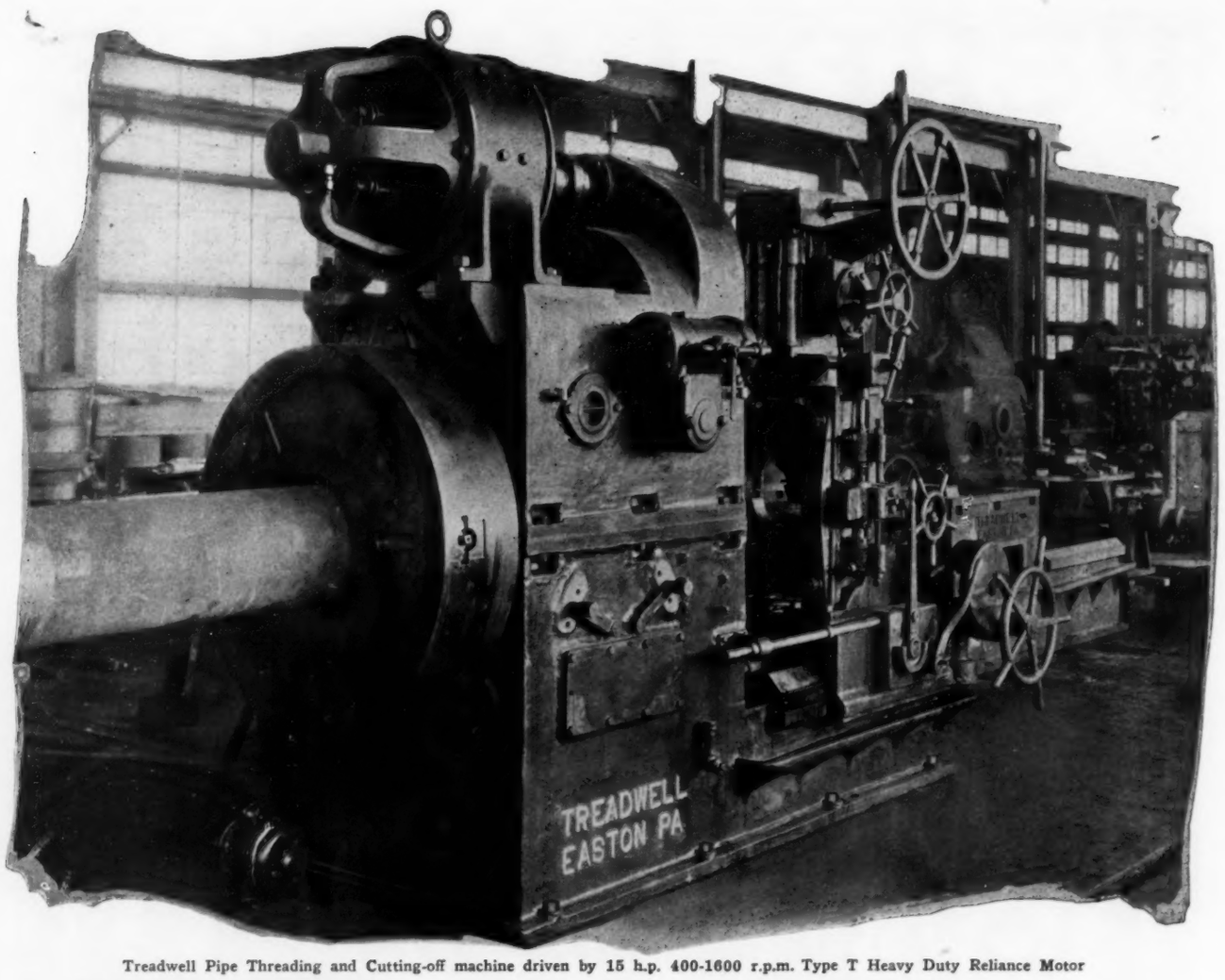
TRADE BussFuses ELECTRICITY'S SAFETY VALVE MARK REG U.S. PAT. OFF.

"ELECTRICITY'S SAFETY VALVE" MEANS

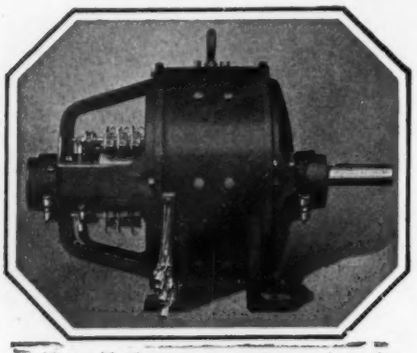
I.&S.E. 12-24

BUSSMANN MANUFACTURING CO.
3819 No. Twenty-Third St., St. Louis, Mo.
Without obligation, send me for examination sample 30 ampere, 250 volt Ferrule Contact Type BUSS Renewable Fuse.

Name _____ Company _____ Position _____
Street _____ City _____ State _____



Treadwell Pipe Threading and Cutting-off machine driven by 15 h.p. 400-1600 r.p.m. Type T Heavy Duty Reliance Motor



Type T Commutators have eight features that are factors in insuring long life in steel mill service. These are illustrated in detail in our Bulletin 2014 which we shall be glad to send.

The Pipe Mills know them

Pipe Mills have given Type T Reliance Motors a good test during the past eight years. They have worked them hard and learned from actual results that these rugged motors will stand the pace. These results have proved the wisdom of getting more of the user's experience into motor design.

Type T Motors were designed to reflect the ideas of Engineers in steel and pipe mills who know how motors must be built to stay on the job longer and be in the repair shop less.

We shall be glad to submit detailed evidence that Type T Reliance Motors will keep down the cost of maintenance in steel and pipe mill service.

Reliance Electric & Engineering Company

1080 Ivanhoe Road, Cleveland, Ohio

BRANCHES:

Boston New York Philadelphia Pittsburgh Cincinnati Detroit Chicago Birmingham, Ala.

Type T Heavy Duty
RELIANCE MOTORS
Direct Current

Silent, Vibrationless Gears

Practically all gears show up equally well in their advertising, but the place to look for their true quality and efficiency is in their service records.

Nuttall Gears have satisfied the most discriminating master mechanics and engineers for over thirty years, and are making wonderful records wherever the service is hardest.

R.D. NUTTALL COMPANY
PITTSBURGH PENNSYLVANIA

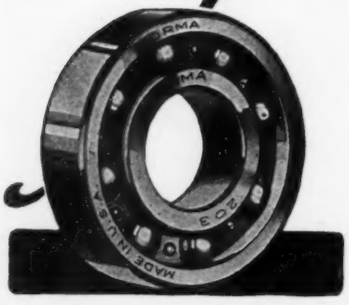
Philadelphia Office
Westinghouse Bldg., 30th and Walnut

Chicago Office
2133 Conway Bldg.

Canadian Agent: Lyman Tube & Supply Co., Ltd.
Montreal and Toronto

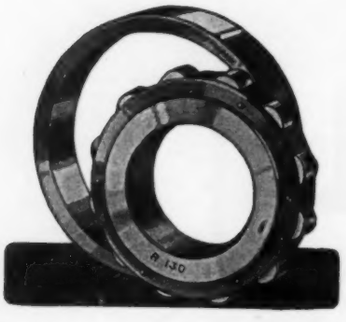
Nuttall

Why Should the Life and the Earning Power of an Electric Motor be Limited by its Bearings?



"NORMA" PRECISION BALL BEARINGS

and
"HOFFMANN" PRECISION ROLLER BEARINGS



MAKE GOOD MOTORS BETTER

Motor windings seldom fail. Good insulations stand up. Commutators wear but slowly. Brushes are easily and inexpensively replaced.

What, then, makes motors "wear out"? What cuts down their efficiency and finally fails?

Experience, alike of motor manufacturer and motor user, furnishes the answer — **inadequate, unreliable, sleeve type bearings.**

Whatever of anti-friction quality a sleeve type bearing possesses, it has by virtue of the lubricant used and not because of any friction-reducing quality in the sleeve type bearing itself.

The success or failure of such a bearing, then, depends upon its lubrication. Inadequate, or neglected, or improper lubrication means the failure of the sleeve type bearing—and this means the failure of the motor.

The one and only complete solution of the motor bearings problem lies in the use of true anti-friction bearings—

Bearings which, though vastly improved in their operation by ample and proper lubrication, are yet not absolutely dependent upon the lubricant for their anti-friction qualities—

Bearings designed to provide, in their mountings, a store of lubricant ample for long periods of high-efficiency operation, without renewal or attention—

Ball Bearings for motors of smaller powers and higher speeds: **Roller Bearings,** for motors of larger powers and heavier duty.

The production cost, to the manufacturer, and the purchase price, to the buyer, may be a little higher for the ball or roller bearing motor.

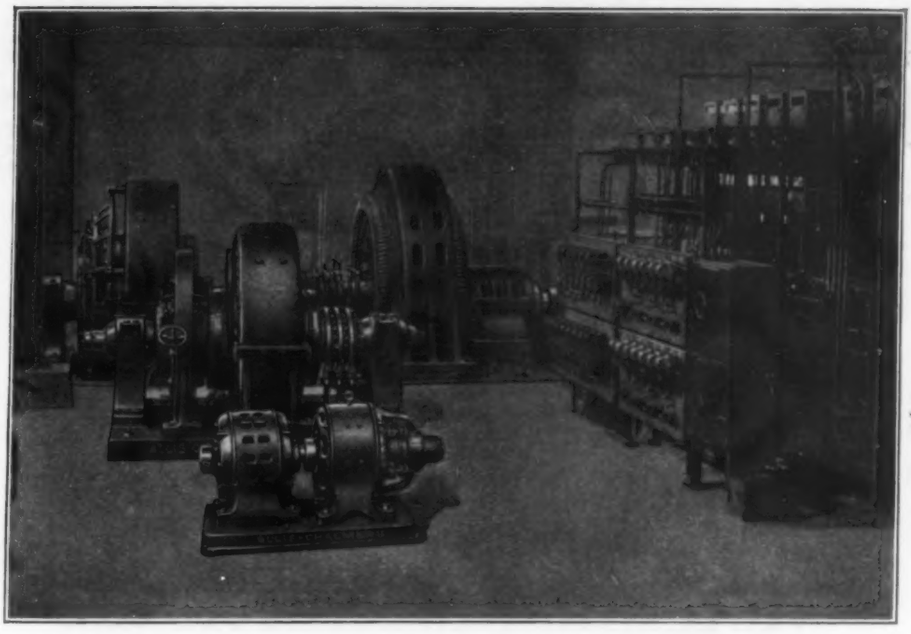
But this difference is far over-shadowed by the subsequent savings resulting—the saving in lubricant, the saving in current, the uninterrupted service, the lower up-keep, the longer life of sustained high efficiency.

NORMA-HOFFMANN BEARINGS CORPORATION

Stamford, Conn.

PRECISION BALL, ROLLER AND THRUST BEARINGS

ALLIS-CHALMERS



Adjustable Speed Rolling Mill Sets

Sets consist of rugged equipment for Steel Mill Service.

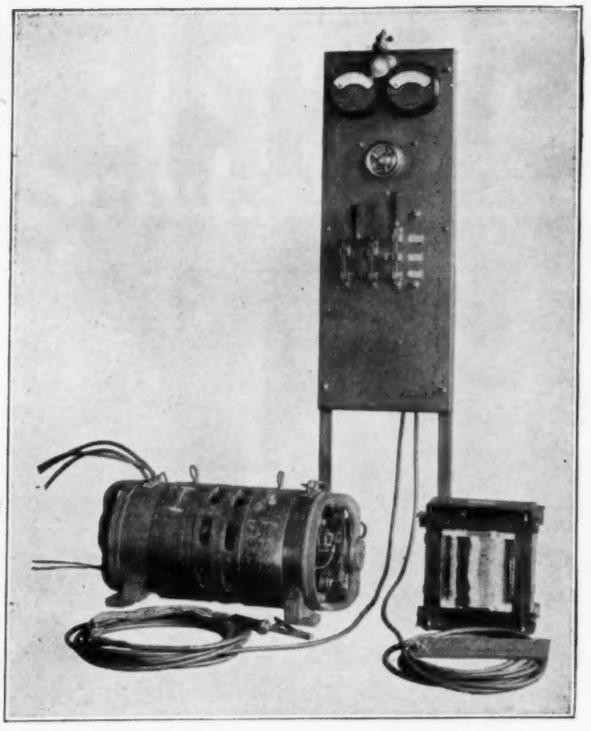
Have all the advantages of induction motor drive with speed adjustment to suit the section rolled.

A speed range of 2 to 1 is readily obtainable, with sparkless commutation throughout the entire range of speed and load.

PRODUCTS:

Electrical Machinery
Gas Engines
Steam Engines
Steam Turbines
Condensers
Oil Engines
Hydraulic Turbines
Pumping Engines
Centrifugal Pumps
Mining Machinery
Metallurgical Machinery
Crushing Machinery
Cement Machinery
Flour Mill Machinery
Saw Mill Machinery
Air Compressors
Air Brakes
Steam and Electric Hoists
Farm Tractors
Power Transmission Machinery

ALLIS-CHALMERS MANUFACTURING CO.
MILWAUKEE, WIS. U.S.A.



Double-acting thrust bearing, flat seats (grooved races) 2100-F Series

Single-acting thrust bearing, flat seats (grooved races) 1100-F Series

Single-acting, self-aligning thrust bearing 1100 Series

Single-acting, self-aligning thrust bearing, leveling washer. 1100-U Series

Double-acting, self-aligning thrust bearing, leveling washers 2100-U Series

Single-row deep-groove Standard type, radial bearing

Double-row, deep-groove Standard type, radial bearing

Angular contact bearing, combination radial and thrust

Double-row, maximum type, radial bearing

Single-row, maximum type, radial bearing

Motor manufacturers are getting in line

Strom Ball Bearing Equipped Motors have many advantages

The principal advantages are:

1—A permanent and uniform air gap between armature and coils.
2—Elimination of oil leakage. This prevents insulation troubles.
3—Starting and running resistance minimized and equalized.
4—More compact motor design due to small bearing space required.
5—End motion of rotor and vibration reduced to a minimum.

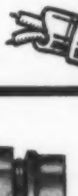
Add to these five points of superiority a marked reduction in cost of maintenance and service, and higher efficiency of the motor, and you have the principal reasons why Strom Ball Bearings are used.

Write to us for further information, catalog and price list. Our engineers will gladly assist you if you will send them your bearing problems. Write.

Strom BALL BEARINGS

STROM BALL BEARING MFG. CO.
Formerly U. S. Ball Bearing Mfg. Co.
4594 Palmer Street, Chicago, Ill.

CONNECTORS



TYPE CGB TYPE CGS TYPE CGK

CONNECTORS

WITH

TAPERED RUBBER BUSHING

For

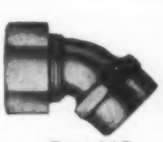
Round Flexible Cord or Cable

OR WITH

TAPERED SPLIT LEAD SLEEVE

For

Flexible Conduit or Armored Cable



TYPE CGL TYPE CGD

Connects to Condulets or Conduit

Write for Bulletin No. 2056

CROUSE-HINDS COMPANY

SYRACUSE, N. Y., U. S. A.

SALES OFFICES

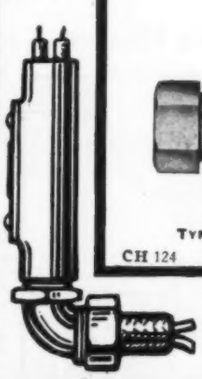
NEW YORK BOSTON CHICAGO

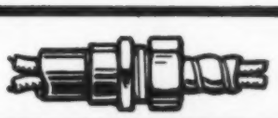
PHILADELPHIA DETROIT ST. LOUIS MINNEAPOLIS

CINCINNATI SAN FRANCISCO

TYPE CGE TYPE CGR TYPE CGM

CH 124





CROUSE-HINDS

Results

Too often, ingeniously worded descriptions and technical trivialities, obscure the *main* issue.

In the long run, the only thing that counts is *Results.* Judged on *Results,* and Results *alone,* the

'UNION'

Renewable Fuse

stands head and shoulders above all other makes. No other fuse withstands so many blowouts or can be renewed so easily and quickly. Therefore

The "Union" is a Good, Dependable Fuse

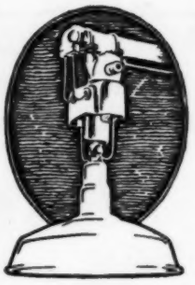
At Leading Dealers and Jobbers
Write for Catalog

Chicago Fuse Mfg. Co.

Manufacturers also of Switch and Outlet Boxes, Cut-Out Bases, Fuse Plugs, Fuse Wire and Automobile Fuses.

Chicago New York

Reflectors *or* Shades?



One is **constructive**—saving the upward portion of the light by bending it downward into the working area. The other is **obstructive** — merely preventing the upward light from going "anywhere."

A dirty reflector makes a first class shade—but it does not save any light

Nothing is gained by adding reflectors to your lighting equipment unless they are kept in a reflecting condition.

The greatest problem in reflector-cleaning is "how to get at it."

The Thompson Safety Lowering Switch helps to solve this problem by making reflector-cleaning easy and safe.

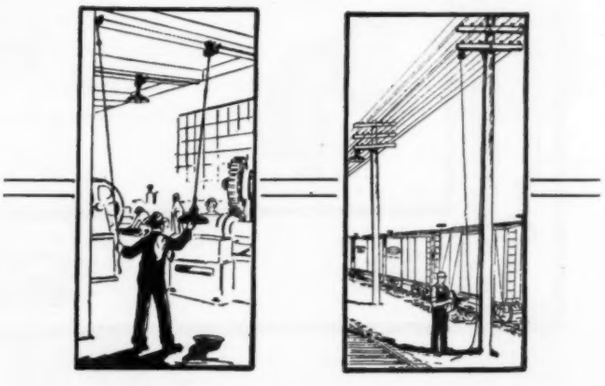
No climbing or electrical hazards

Inexpensive and easily included in present lighting systems.

THOMPSON

Safety LOWERING Switch

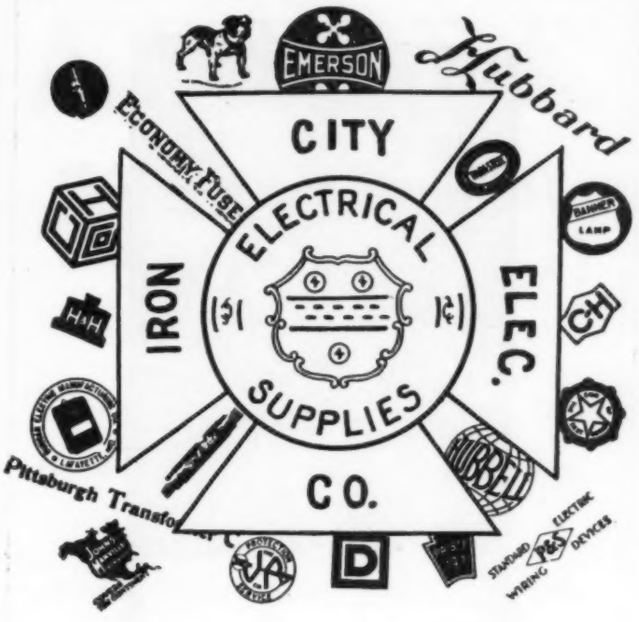
—or Disconnecting Hanger



Write for Catalogue B-22 for details

The Thompson Electric Co.

226 St. Clair Ave. N. E. CLEVELAND, OHIO



The Trade Mark

of the

Iron City Electric Co.

436-38 Seventh Avenue

Pittsburgh, Pa.

REPRESENTING

"The House That Service Built"

IS BACKED BY A GROUP OF

TRADE MARKS

of Well Known Manufacturers Guaranteeing the Quality of the Goods You Receive

---

1891 — 1924

MORGAN

Construction Company

Worcester, Mass., U.S.A.

Designers and Builders of

Morgan Continuous Mills

for

Billets, Sheet Bars, Skelp, Merchant-Bars, Hot-Strip, Rods

also

Wire Drawing Machines
Producer Gas Machines
Straightening Machines
Isley Reversing Valves
Re-Heating Furnaces
Reducing Gear Units
Shears

Our Engineering Department

is prepared to solve successfully your problems in design or arrangement of plant and equipment from open hearth to finished product

1891 — 1924

Electrical Engineering and Manufacturing Company

General Offices:

PITTSBURGH, PA.

We are prepared to furnish your requirements in the following materials and equipment:

"MORGANITE" Carbon-Graphite Metal Brushes.

"ROWAN" Automatic Controllers and Starters.

"SUMET" Bronze and Babbitt Bearing Metals.

"SCHENECTADY" Electrical Insulating Varnishes and Compounds.

"BELL" Cedar Poles.

CROSSARMS: Douglas Fir and Pine.

LINE MATERIALS: Hangers, Brackets, etc.

TRACK GRINDERS: Reciprocating, Rotating, and Swing Frame.

"AJAX" Resistance Type Welding and Bonding Machines.

"UNA"—Arc Welding Dynamotors, Rail Bonds, Rail Joints, and Welding Rod.

MINE HOISTS and Winches, Car Pullers, etc.

HIGH and **LOW** Tension Insulators.

"ELPECO" High and Low Tension Switching Equipment, Bus Fittings, etc.

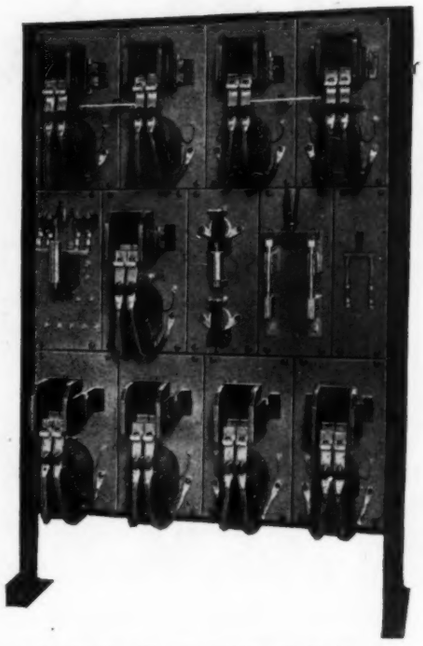
"BENNETT" Lightning Arrestors.

We have a corps of expert engineers, specialists in the above lines, who will be glad to give immediate attention to your inquiries or to see you at your request for consultation regarding applications or equipment. Call or write our nearest office.

CINCINNATI, OHIO
607 Mercantile Lib. Bldg.
Phone Main 3257

CLEVELAND, OHIO
320 Union Bldg.
Phone Prospect 1252

PITTSBURGH, PA.
907-909 Penn Ave.
Phone Grant 6693-4



150 H.P. Type 4750 Full Speed Reversing Mill Controller

Automatic Motor Starters and Controllers

for

Alternating and Direct Current Electric Motors

May we send our nearest representative to see you?

ROWAN CONTROL

THE ROWAN CONTROLLER CO., BALTIMORE, MD.

A. I. & S. E. E.

IRON AND STEEL COST and PRACTICE CHART

Investment and Operating Costs

Coke Ovens, Blast Furnaces, Open Hearth, Blooming Mill Power House

No chart, no figures, have ever appeared in print, covering in detail the investment and operating charges of producing coke, pig iron and steel.

This chart is valuable for reference to the Steel Mill President, Vice President, General Managers, General Superintendents, Superintendents and Engineers.

Price $3.00

Association of Iron & Steel Electrical Engineers
706 Empire Bldg., Pittsburgh, Pa.

Mpundulu

The mpundulu is a spirit used by the kaffir to throw spells on other people.

Unless one is able to keep the head in some water the mpundulu cannot be seen.

Operators over here often see similar mpundulu when water doesn't even enter the consideration.

Anything that gets heavy on the nerves brings similar visions—such as the chattering of misapplied carbon brushes.

That's why we feel that we're doing a real humane work to pull off such brushes and prescribe the proper Morganite.

The silent hush of Morganite soothes the mind—replaces nerves with nerve.

MORGANITE BRUSH CO., INC.
519 West 38th St., New York City
DISTRICT ENGINEERS AND AGENTS

Morganite

Electric Power Equipment Corp., 412-420 North 18th St., Philadelphia, Pa.

O. T. Hall, Sales Engineer, 1926 Edmonson Ave., Baltimore, Md.

Electrical Engineering & Mfg. Co., 909 Penn Ave., Pittsburgh, Pa.

Electrical Engineerng & Mfg. Co., 422 Union Bldg., Cleveland, Ohio.

Special Service Sales Co., 502 Delta Bldg., Los Angeles, Calif.

J. F. Drummey, 75 Pleasant St., Revere, Mass.

Special Service Sales Co., 202 Russ Bldg., San Francisco, Calif.

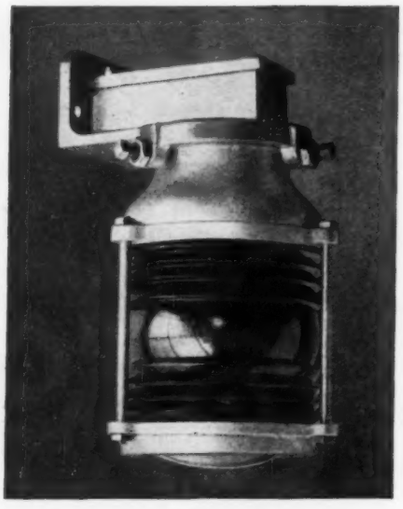
Electrical Engineering & Mfg. Co., 607 Mercantile Library Bldg., Cincinnati, Ohio.

Railway & Power Engineering Corp., Ltd., 131 Eastern Ave., Toronto, Ontario, Canada.

Railway & Power Engineering Corp., Ltd., 326 Craig St., West, Montreal, Canada

Railway & Power Engineering Corp., Ltd., P. O. Box No. 325, Winnipeg, Canada

You need a lot of Little Brothers



"Little Brother"

If you looked around you'd find more genuine uses in your plant and yards for Little Brother Universal Lanterns than you could shake a stick at. Because—the first cost is moderate and there is practically no maintenance.

Size, shape and weight make them adaptable indoors and out. And they're made of cast aluminum—**light weight** that resists **rust** and **acid atmosphere.** Corning Fresnal lens in ruby, green, yellow or clear; Corning Clear lens in base. Write for complete description of "Little Brother" and other Universal Signal Lanterns.

The Nichols-Lintern Company
7960 Lorain Ave.,
CLEVELAND, OHIO

N-L Products Mfd. and Sold in Canada by Railway & Power Eng. Corp., Ltd., 133 Eastern Ave., Toronto, Ont.

Do you know why

USG

BRUSHES

are better?

Catalog B-3 will tell you.
Write for your copy today.

USG

on every brush

THE UNITED STATES GRAPHITE COMPANY

Saginaw, Michigan, U. S. A.

District Offices

New York **Philadelphia** **Pittsburgh** **Chicago** **St. Louis** **San Francisco**

AT LAST! An Alternating Current Combination Volt-Ammeter

Roller-Smith takes particular pride in presenting its latest contribution to the instrument art—**a combination volt-ammeter for alternating current.** Convenient in size, light weight, rugged and—**above all**—accurate and reliable.

The Type GSA Volt-ammeter and other Type GSA instruments are fully described and listed in Bulletin AK-160.

Your copy is ready for you. Send for it.

BALTIMORE, 113 E. Franklin St.
BIRMINGHAM, Brown-Marx Bldg.
BOSTON, 141 Milk St.
BUFFALO, Ellicott Square
CHICAGO, 430 So. Green St.
CLEVELAND, 7016 Euclid Ave.
DALLAS, 2002½ Live Oak St.
DENVER, U. S. Nat'l Bank Bldg.
DETROIT, Ford Bldg.
LOS ANGELES, Consolidated Bldg.
MEMPHIS, 493 S. Main St.
MONTREAL, Power Bldg.

ROLLER-SMITH COMPANY
Electrical Instruments Meters and Circuit Breakers

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RUMSEY
ELECTRIC COMPANY
Electric Supplies and Machinery
Everything in Radio
1007 Arch St.
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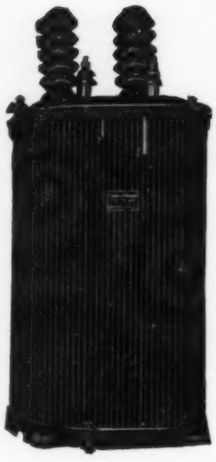
MOLONEY
TRANSFORMERS



WE have been manufacturing transformers now for over a quarter of a century—a long time in an industry so young.

Moloney Engineering Experience has dealt with the transformer in every phase of its development.

From the first, Moloney Engineers have been animated by a two-fold purpose: to build the highest attainable quality, and to build it economically.

Moloney Transformers are recognized by all transformer users as the highest standard—a fact which demonstrates the success which has crowned the efforts of Moloney Engineers.

MOLONEY ELECTRIC CO.
Manufacturers of Transformers Exclusively
FACTORY AND MAIN OFFICE
St. Louis, Mo.
Offices in All Principal Cities

For Plant Haulage and Switching

Plant managers are beginning to realize the unquestioned fact that the steam dinky is antiquated and expensive. Many of them find large Irontons less costly and more dependable for switching, while small Irontons save money for hauling on narrow gauge track inside the plant yards. Both work 24 hours a day when desired.

Let Ironton Engineers survey your conditions and make a report.

The
IRONTON
Engine Co.
Ironton, Ohio

Wagner Quality

BUILT LIKE A WATCH

To Our Friends in the Iron and Steel Field

We wish you a very merry Christmas and trust that the year 1925 will be filled with Prosperity and Happiness for you.

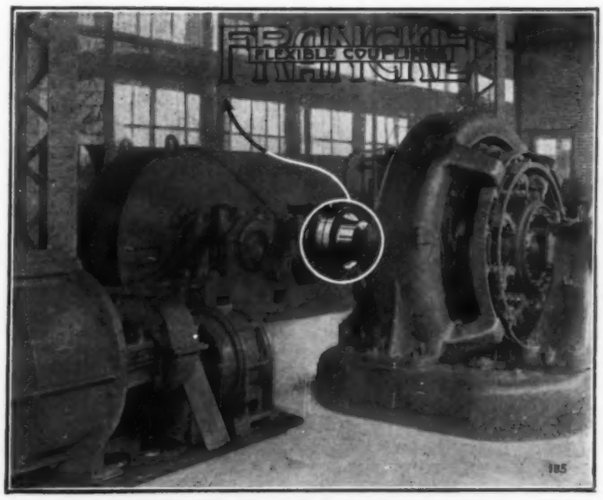
LUDWIG HOMMEL & CO.

929 Penn Avenue
PITTSBURGH, PA.

LUDWIG HOMMEL & CO.

Rose Building
CLEVELAND, O.

Flexible Couplings for every service



5 Types of Francke Flexible Couplings.

Pressed Steel Type—for Fractional H.P. drives.
Heavy Pattern Type—a general purpose coupling.
High Speed Type—for high speed drives.
Double Type—for heavy duty, continuous drives.
Marine Type—used on small power boats.

FRANCKE FLEXIBLE COUPLINGS

"They make good machines last longer"

In all Francke designs laminated steel springs provide for shaft misalignments in every direction. They cushion load shocks and vibrations. Where needed they also act as a safety device.

Ask for Bulletin No. 37.

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Coupling Specialists Since 1912.

64 Washington Street, Newark, N. J.

District Office, Fulton Building, Pittsburgh

Herringbone Mill Pinions

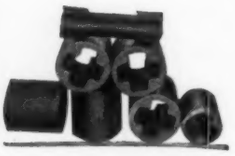
Motor and Crane Gears

Mill Table Gears

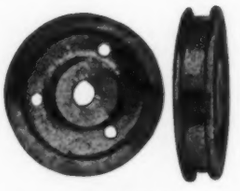
Herringbone Gears

Cincinnati "Tool Steel" gears outlast 8 to 10 Untreated and are much stronger

Tool Steel Face
as hard here as on the very surface (This is one of the great differences between tool steel and case-hardening methods)
Toughened Centre



Coupling Boxes and Spindles



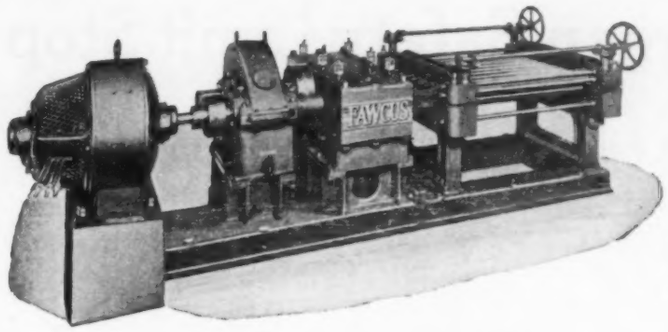
Crane Wheels

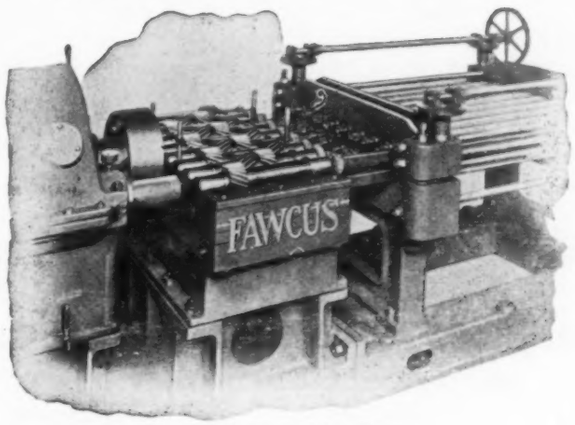
The Tool Steel Gear and Pinion Company
CINCINNATI, OHIO

Pittsburgh Transformer Company

Largest Manufacturers of Transformers Exclusively in the United States

Pittsburgh, Pennsylvania





Gear Box for Driving Rollers

FAWCUS
Sheet Roller Leveler

Designed for the production of an improved product in cold rolling sheets. The use of Fawcus Herringbone Gears throughout eliminates all vibration and gives a steady uniform velocity to the rolls, overcoming the marking of sheets, and producing a perfect sheet without buckles, waves or riffles.

The same type of leveler has been devolped for strip mill product with shorter rolls and lighter construction, but of the same general design. This machine can be built with the entering rolls adjustable also, while in the machine illustrated the last roll only has independent adjustment.

FAWCUS MACHINE CO.
PITTSBURGH, PA.

REPRESENTATIVES

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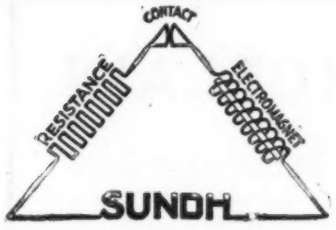


Steel Men!

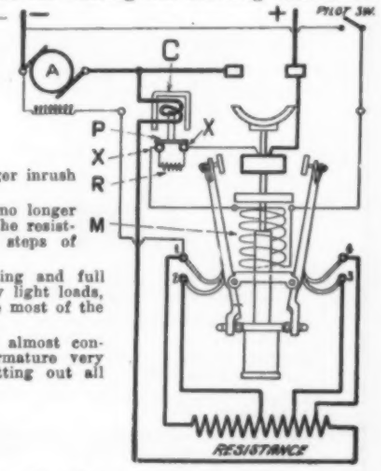
Isn't this what some of you wanted, as brought out in your discussion of control in your Journal of November, 1921? A control that would have definite time limit modified with current limiting element?

You want a starter to obey its real function, don't you? i. e., to start and accelerate a motor by cutting in resistance, then out, in the shortest possible time in relation to the load. You want the motor to "mote" if it's at all possible to do so, whether the voltage is high or low, or whether there is excessive friction on a cold Monday morning. If the first current inrush does not start it, the next one may. If we can't get it to start on small amounts of current, we want to provide automatic means of increasing the current or power so that it will start, provided that no one has placed a crowbar in between the gears or there happens to be a short circuit. In that case, overload circuit opening devices take care of the condition.

We have been using this method since 1911. On large size motor starters, reversing and non-reversing, we use the multiple level starter as a pilot relay whose multi-contact energizes large shunt wound switches for cutting out starting resistance.

The action of this control is easily understood from the diagram, and the following description of operation:

The relay C is in series with the armature only during the starting period and is normally set to operate at about 130% of normal current. When the current in the armature of the motor equals or exceeds this setting on the starting inrushes, the armature of the relay lifts the plate P from the two contacts XX and by this action inserts the resistance R in series with the solenoid coil M of the automatic starter. The resistance R can be made to have a resistance so that when inserted in the circuit of the coil M (by action of excess load on the armature of motor at start) it partly destroys the effective magnetic pull of coil M and prevents the cutting out of any more resistance in the armature circuit, but at the same time there is sufficient magnetic pull to lift the core very slowly so that in time, even with the insertion of this resistance in the magnet coil circuit, the next succeeding step of resistance will be cut out, giving a larger inrush current to the motor.



Under normal conditions as soon as the current in the armature reduces to about normal, the coil C can no longer hold up plate P and it consequently drops, thus closing the circuit across contacts XX, and short circuiting the resistance R, allowing coil M to be again fully energized and to act with full power, thus cutting out succeeding steps of resistance quickly.

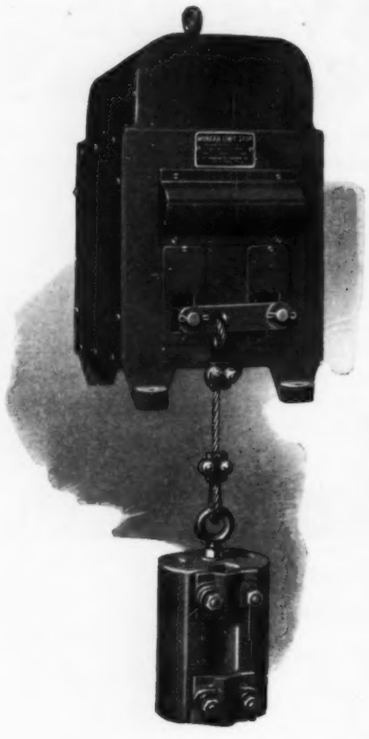
The retarding action caused by excess load on coil M may take place during any interval between starting and full running position. The time of the dash pot is generally set for a minimum of 1½ seconds, which in case of very light loads, the cutting out of resistance would take approximately this time, since the series relay coil C plate XX, would be most of the time short circuiting the resistance R.

Under abnormal, extremely heavy loads, where the series coil C would lift its armature and hold it up almost continuously, thus inserting all the resistance in the coil, R circuit on automatic starter coil M would lift its armature very slowly against the action of the dash pot and light pulling force, and may take up to 15 seconds before cutting out all resistance.

The resistance R may be made of a value as to either increase or decrease the pull of magnet coil M.

Write for Catalog.

SUNDH ELECTRIC COMPANY **Newark, N. J., U. S. A.**



Morgan Safety Limit Stop

WACKERLY TYPE

For All Types of Direct Current Motors

A FEW OF THE ADVANTAGES

No heavy current broken by contactors.

Limit Stop can be connected up with any standard make of controller.

No extra conductors required.

Normal lowering circuits established immediately upon reversal of controller. No waiting to lower through resistance.

No external banks of resistance. Limit Stop is self contained.

Only one swinging weight used, this being guided by one of the hoisting ropes.

Positive in action. A movement upward of weight of a fraction of an inch will actuate limit stop.

Occupies minimum floor space on trolley.

Sequence of operation of contactors obtained by simple system of levers. No cams, springs or counterweights used.

For full particulars on this stop send for Bulletin No. 29.

The Morgan Engineering Co.

Alliance, Ohio

CHICAGO
122 So. Michigan Ave.

NEW YORK
120 Broadway

PITTSBURGH
1420 Oliver Bldg.

LAPP HIGH VOLTAGE PORCELAIN

Did you ever hear of a failure of a Lapp Insulator?

Seven years of production—including highest voltage pin and suspension types —without a failure!

There is the reason for use of Lapp Insulators, besides which—for "trimmings" —they provide unexcelled mechanical strength.

Lapp vacuum process of porcelain production, surfaces of porcelain glazed all over, Lapp over potential test methods.

Lapp Insulators Do Not Fail?

LAPP INSULATOR CO., Inc., LeRoy, N. Y.

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ALLIANCE CRANES

Largest Builders of the World's Largest Cranes

204 of 100 Tons Capacity and Over

STANDARD CRANES

55	100	tons
2	115	tons
42	125	tons
24	150	tons
22	175	tons
2	200	tons
1	225	tons
1	250	tons
3	430	tons

STRIPPING CRANES

8	100	tons
1	125	tons
19	150	tons
13	200	tons
1	Single Ram, 320	tons

COMBINATION CHARGERS AND STRIPPERS

3	100	tons
3	150	tons
4	200	tons

W. E. FINISH SALAMANDER

magnet wire is particularly adapted for rewinding field and armature coils, solenoids, etc., and is used extensively in the steel industry. It is acid-proof, moisture-proof, oil-proof, heat-resisting and has an extremely tough, smooth, hard finish.

For further information write to our nearest representative for Salamander wires and cables—

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Cleveland, Ohio ... H. Lee Reynolds Company, 309 Plymouth Building
Denver, Colo. ..... Franklin Sales Company, Denham Building.
Los Angeles, Cal. .. A. S. Lindstrom, 1144 Maple Avenue
Philadelphia, Pa. ..... F. K. Simons Electric Co., Fuller Building
Pittsburgh, Pa. ..... H. Lee Reynolds Company, Oliver Building.
Portland, Ore. ..... A. S. Lindstrom, 312 McKay Building
Salt Lake City, Utah .. Raymond Ackerman, 419 Dooly Building
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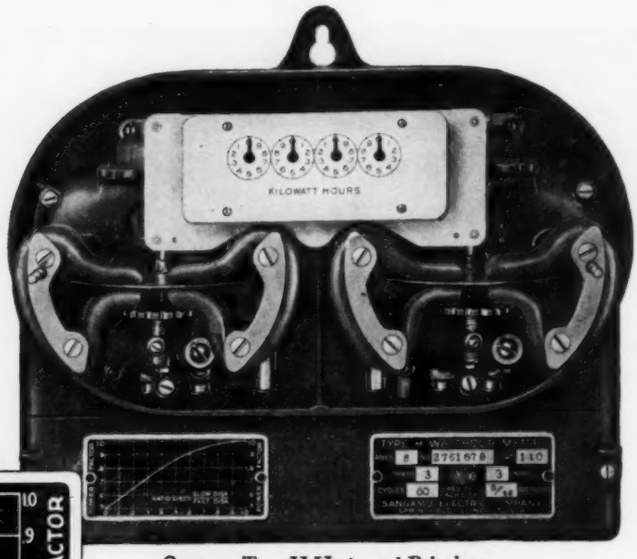
YORK INSULATED WIRE WORKS

of General Electric Company

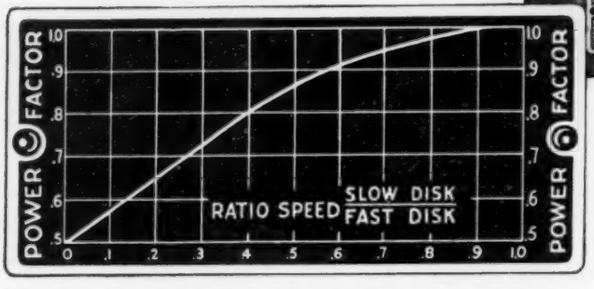
Works: York, Pa. Office: 1737 Broadway, N. Y. C.

SANGAMO



Sangamo Type H Horizontal Polyphase Watthour Meter with cover removed.

Graph on terminal-box door which permits ratio of disk speeds to be translated readily into power-factor.



Analyze your motor load
and reduce power costs

CHANGING production conditions frequently reduce the load far below what was figured when your motors were installed. Motors operating at reduced load have low efficiency and low power-factor, resulting in undue waste of energy and many times in extremely annoying voltage conditions. With a Sangamo Horizontal Polyphase Watthour Meter you can follow the energy consumption and at will check the power-factor which is a direct indication of the effectiveness with which you are employing the capabilities of your motor. Then by shifting motors that are lightly loaded to the heavier tasks, conditions may be brought into closer balance, with the resulting saving in energy and improvement in plant operation.

The desirability of accurate departmental costs dictates the use of watthour meters in industrial plants, and the Sangamo Horizontal Polyphase Watthour Meter has the advantage in serving the dual purpose of recording the energy consumed and at the same time checking whenever desired the power-factor of the load.

This meter combines two single-phase Type H elements side by side in a single base, the register being geared to both elements, and so designed as to record the algebraic sum of their revolutions. All construction details, except the base and register, are the same as those used for over ten years with such marked success on Sangamo Single-phase Type H Meters.

On balanced load the relative rates of rotation of the two elements is a measure of the power-factor of the load. A graph on the terminal-box door permits the ratio of disk speeds to be translated directly into power-factor.

Write for Bulletin 67 which describes and illustrates the Sangamo line of single and polyphase watthour meters.

SANGAMO ELECTRIC COMPANY
Springfield, Illinois
New York Chicago Birmingham San Francisco Los Angeles

SANGAMO METERS
FOR EVERY ELECTRICAL NEED

6220-2B

PYLE-O-LYTES

The Brighter Flood Lights

for all **Industrial Night Lighting**

In the Lumber Regions

In the Steel Centers

Increase Production

Cut Down Overhead

Write for Catalogue No. 4

In the Oil Fields

In the Railroad Centers

The PYLE-NATIONAL COMPANY

1334-58 N. Kostner Ave. Chicago, Ill.

Canadian Agents—The Holden Co. Ltd. Montreal-Winnipeg-Vancouver-Toronto

The Preferred Fittings

WHEREVER a neat, quick and economical job of wiring is desired, "Unilets" are invariably preferred. This preference is due largely to their individual design and manufacture. And being adaptable to any fitting requirement, they simplify installation operations and reduce material and labor costs.

"Unilets" are light, strong, easy to handle and install; provide 50% more wiring space, low transportation charges, and eliminate breakage in handling and shipping. Made with flat bottoms they fit securely against wall or ceiling.

"Unilet" distribution is nation-wide, which assures prompt deliveries and affords standardization of these fittings for all wiring work. Catalog 9-D contains hundreds of fittings, pictorially indexed. If you haven't a copy, write for one today.

APPLETON ELECTRIC COMPANY
General Offices and Factory
1704 Wellington Avenue
CHICAGO

Type "WDC" Unilet with 3-wire Porcelain Cover

Type "SE" Unilet with Pony Receptacle

Type "GN" Unilet with Octagonal Porcelain Receptacle

Type "FS" Unilet with Cover for Plug Receptacle

Type "T" Unilet with "Unitap" Connection Block

Type "GSC" Unilet with Operating Handle for Snap Switches

Type "MSC" Unilet with Receptacle and Special Cover

Type "GN" Unilet with Inter-Connecting Block Body

Type "FWC" Unilet with Cover for "Duplex" Receptacle

Type "FS" Unilet, 2-gang with Cover for Toggle Switches

APPLETON UNILETS
STANDARD FOR BETTER WIRING

40th Anniversary
1884—1924

KEYSTONE ACCOMPLISHMENTS

No. 5 of a series

"We are using Keystone Grease No. 119 (heavy) Density for monorail wheels, and it is just right.

"The brass bearings on monorail wheels cost $3.75. There are 72 wheels in use in which these brass bearings are used. Before using Keystone Grease we renewed bearings at the rate of two a day.

"We have ended this now. Since using No. 119 (heavy) density there hasn't been one single bearing replaced. Previous to this time we used oils and all kinds of grease without satisfactory results, so we feel this proves that there is no lubricant equal to Keystone Grease."

—the experience of another plant executive.

. . .

Conditions in your plant may be different—perhaps a talk with a Keystone Sales Engineer would profit you nothing—but to be absolutely certain, talk with the Keystone representative next time he calls. Have your own proof. Do this one thing and we will feel we are doing our job 100%.

KEYSTONE GREASE

YOUR machinery represents a heavy investment. The best insurance you can put on it is a good lubricant.

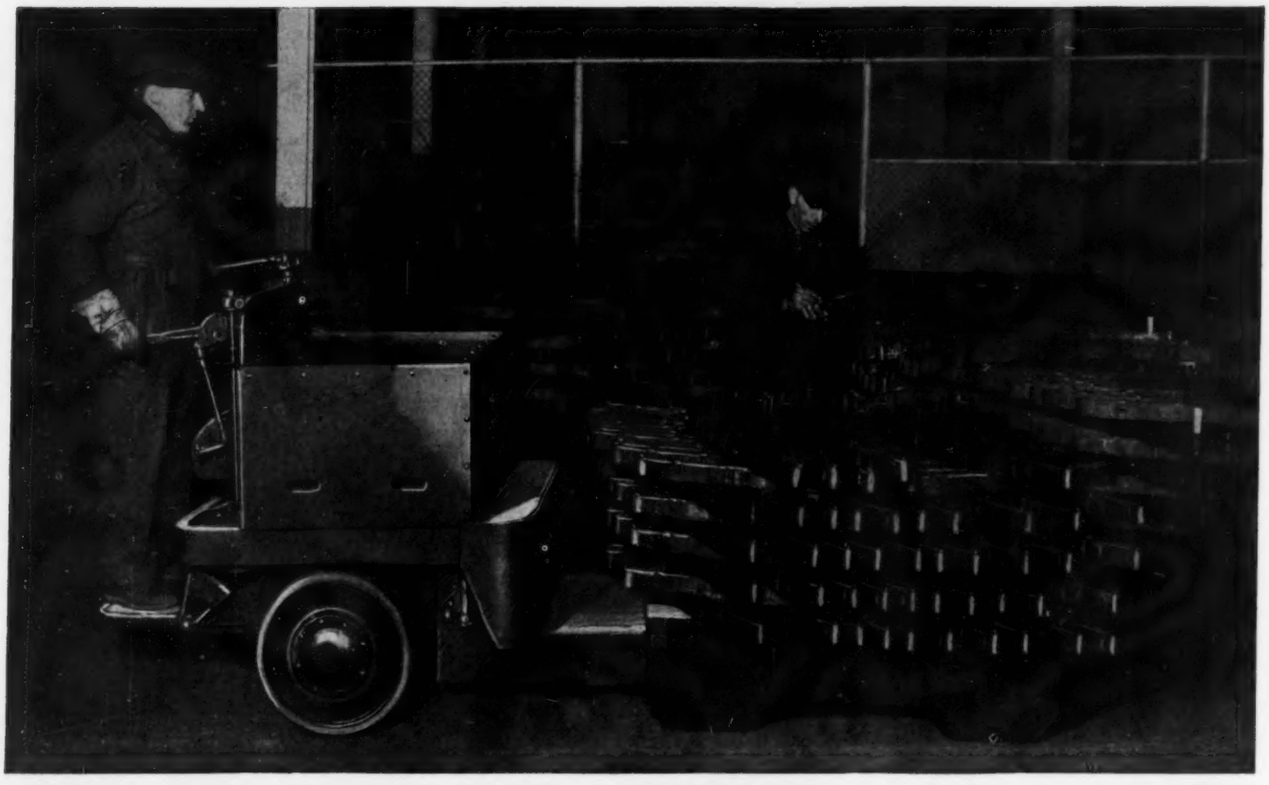
Keystone Grease is a pure petroleum product, made in densities to suit various conditions. It is as honest a lubricant as can be made and will keep your machinery depreciation at a minimum. Proof? We have it. Write. THE KEYSTONE LUBRICATING COMPANY, *Est. 1884, PHILADELPHIA, PA.*, at 21st & Clearfield Streets.

Keystone Grease

The Master Lubricant

For Every Industry

Reg. U. S. Pat. Off.



One of the Baker Trucks at the Perfection Spring Plant of the Eaton Axle Co., Cleveland, Ohio

Ability *plus* Versatility

TO PICK up a load at the receiving platform, carry it quickly down crowded shop aisles, up steep ramps, and around corners that look impossible, is only one use of the Elevating Truck.

Whenever material must be handled between departments—from one operation to another—from storage to railroad cars or commercial trucks—this stout-hearted truck can speed up operations and cut costs to the minimum.

A truck like this, that never tires on the busiest day and is always on the job when you need it, saves enough in six months to cover the invoice for the equipment. All further saving is pure profit.

Write for the complete Baker catalog covering all kinds of electric tractors and trucks or, without obligation, ask for information on the best type for special requirements.

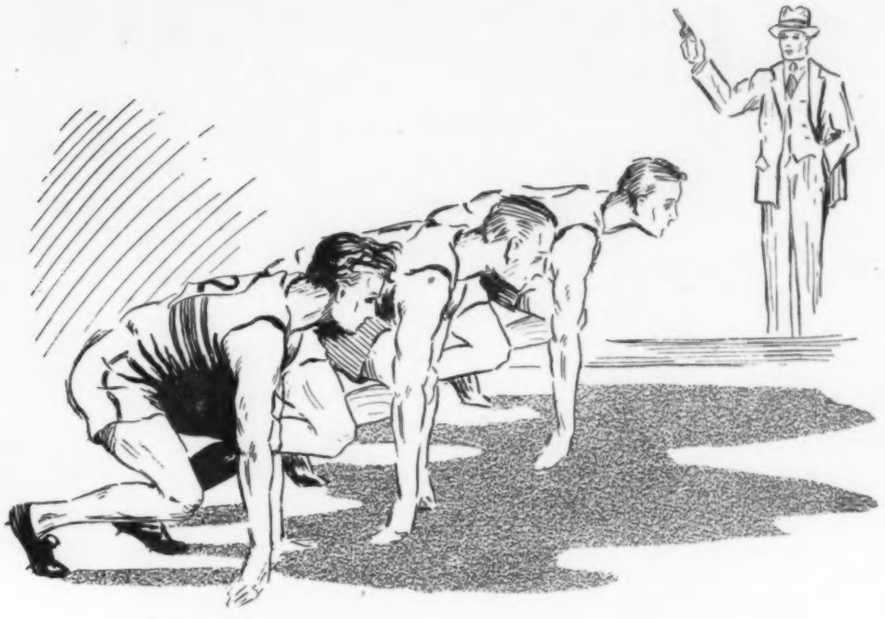
Baker Industrial Division

THE BAKER R & L COMPANY · · CLEVELAND, OHIO

ELECTRIC TRACTORS AND TRUCKS

TRADE-MARK REG. U.S. PAT. OFF.

Baker



Are You Ready?

Increased production is predicted on all sides. Are you ready to meet the needs of a rapidly increasing market by meeting demand with production?

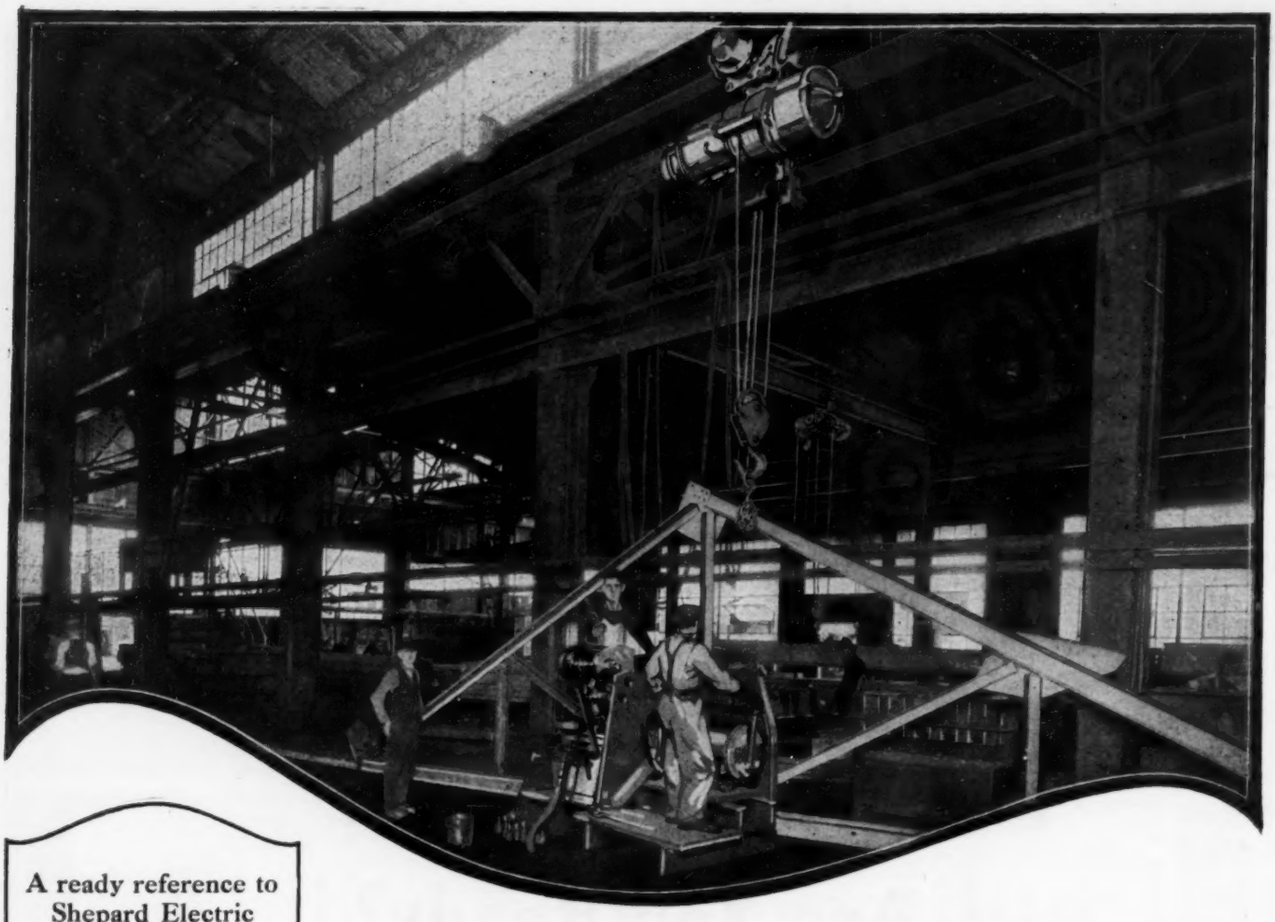
If your equipment is modern and flexible you have an advantage in a field where competition is getting keener and keener. If not, are you going to stand aside like an unconditioned runner and see the fruits of preparedness go to the other fellow.

What better time could one find than the beginning of the new year to reduce your power costs? Undoubtedly our engineers can lend material assistance in making such a study. Their services are free and yours to command.

Commercial Department

Duquesne Light Company

435 Sixth Avenue, Pittsburgh, Pa.



A ready reference to Shepard Electric Hoists

This new Shepard Floor Operated Electric Hoist Catalog contains complete data on every type of hoist — dimensions, specifications, prices, dimensional drawings, portrait views, installation views, descriptions — all systematically arranged so that you can easily determine the right type of hoist for your requirements.

Thousands of lifts every day

It takes a sturdy hoist to meet the steady day in, day out lifting service demanded at the pit riveter in the Memphis plant of the Virginia Bridge & Iron Co.

It is jobs like this that prove the "stamina" of Shepard Electric Hoists. They are designed and built to give the utmost in SERVICE—on that basis they are by far the most economical hoist you can buy.

Write for—

the ready reference to Shepard Electric Hoists. It will be of invaluable aid to you in determining the right hoist for your requirements.

SHEPARD ELECTRIC CRANE & HOIST CO.
376 Schuyler Ave., Montour Falls, N. Y.
Branches in Principal Cities. Member Electric Hoist Mfrs.' Assn.

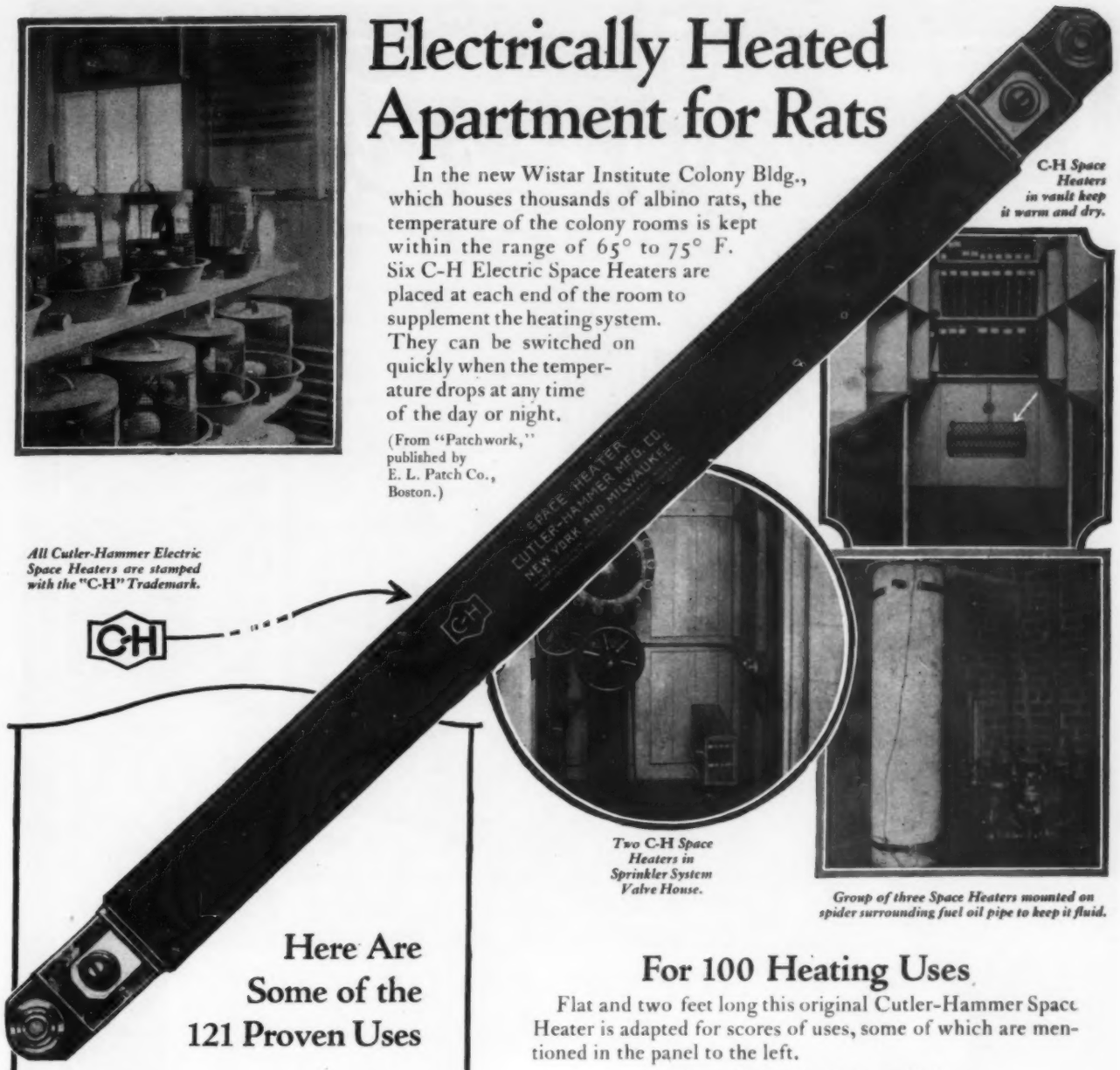
REG. U.S. PAT. OFF.

SHEPARD
ELECTRIC CRANES & HOISTS

Electrically Heated Apartment for Rats

In the new Wistar Institute Colony Bldg., which houses thousands of albino rats, the temperature of the colony rooms is kept within the range of 65° to 75° F. Six C-H Electric Space Heaters are placed at each end of the room to supplement the heating system. They can be switched on quickly when the temperature drops at any time of the day or night.

(From "Patchwork," published by E. L. Patch Co., Boston.)



All Cutler-Hammer Electric Space Heaters are stamped with the "C-H" Trademark.

C-H

C-H Space Heaters in vault keep it warm and dry.

Two C-H Space Heaters in Sprinkler System Valve House.

Group of three Space Heaters mounted on spider surrounding fuel oil pipe to keep it fluid.

Here Are Some of the 121 Proven Uses

Sprinkler Systems	Incubators
Valve Houses	Brooders
Gum Drying Ovens	Around Fuel Oil Pipes
Negative Drying Cabinets	In Watchman Towers
Room Heating	Cafeteria Serving Tables
Mine First Aid Stations	Vaults
Theatre Ticket Booths	Garages
In connection with Ventilating Systems	Warming Ovens
Crane Cabs	Foot Warmers
Coal Tipples	Substations
	Pits
	Manholes

For 100 Heating Uses

Flat and two feet long this original Cutler-Hammer Space Heater is adapted for scores of uses, some of which are mentioned in the panel to the left.

Clean, Safe, Easily Installed
500 Watts (like an Electric Iron)

The insulated mounting eyelets make installation easy. Connection may be made to either direct or alternating current light or power circuits.

If your electric supply jobber cannot supply you promptly, get in touch with the Cutler-Hammer branch office nearest you.

Send for this booklet

THE CUTLER-HAMMER MFG. CO.

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Philadelphia: Com'wealth Bldg.
Cleveland: Guardian Bldg.
Cincinnati: 415 Dixie Terminal Bldg.
Boston: 52 Chauncy St.
Detroit: 536 Hofman Bldg.
St. Louis: 2111 Ry. Exch. Bldg.
Buffalo: 358 Ellicott Sq. Bldg.
New Haven: P. O. Box 1405
Wilkes-Barre, Pa.: 916 Coal Exchange Bldg.

Northern Electric Co., Ltd., Canada

CUTLER-HAMMER

HONEST VALUE

The registered Trade-mark "Packard is never seen except on goods of honest value."

A new plant—modern to the last word—puts us in a position to render the Electric Light and Power industry a truly remarkable service and at the same time maintain the standard of quality for which Packard is so widely known.

Service is defined in the above sentence as getting what you want—WHEN YOU WANT IT." The next time you need transformers of any kind it will pay you to get a Packard proposition.

The Packard Electric Company

Warren, Ohio

Transformer Manufacturers Since 1890

AIR!

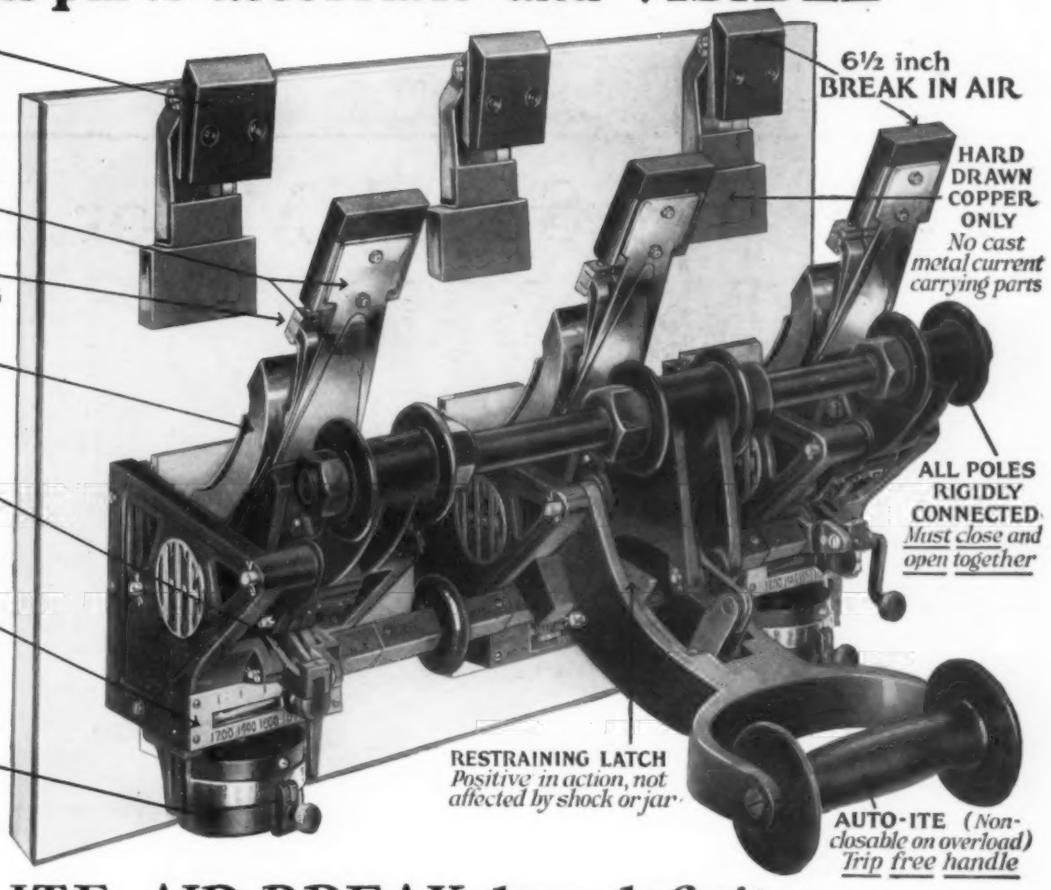
I-T-E CIRCUIT BREAKERS

For Alternating Current

600 VOLTS OR LESS

Give protection without complication

All parts accessible and VISIBLE


COPPER JACKETED PRESSURE CARBONS
For initial contact and final break
Mechanically strong
Electrically perfect
PHOSPHOR BRONZE CARBON SUPPORTS
HEAVY METALLIC SECONDARY BREAKING CONTACTS
LAMINATED BRIDGE
Each leaf individually formed - Heavy even pressure on every Lamination
CLOSING TOGGLES
Afford heavy contact pressure with easy closing
OVERLOAD
Direct acting. Long scale calibration. No relays or series transformers
DALITE
(Direct acting time limit) feature. Adjustable from zero to maximum time. No relays
6½ inch BREAK IN AIR
HARD DRAWN COPPER ONLY
No cast metal current carrying parts
ALL POLES RIGIDLY CONNECTED
Must close and open together
RESTRAINING LATCH
Positive in action, not affected by shock or jar
AUTO-ITE (Non-closable on overload)
Trip free handle

I-T-E AIR BREAK has definite advantages not present in the oil breaker

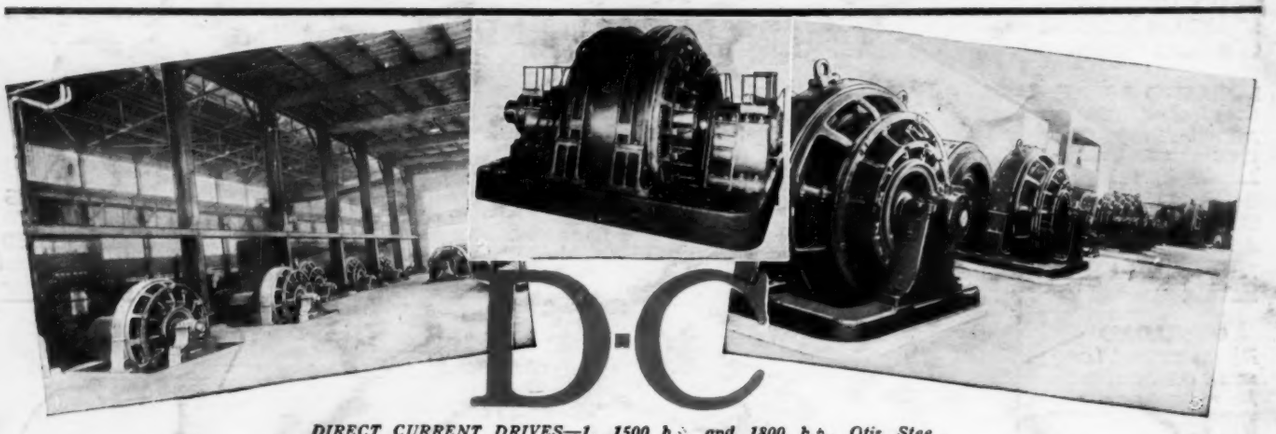
1. *No oil — to leak, carbonize, burn or explode — Just air.*
2. *No tanks to conceal anything — or the lack of it.*
3. *No cells — nothing which needs or deserves to be imprisoned — Just a faithful and efficient servant.*
4. *Inherent simplicity — with resulting low cost of installation and maintenance.*

The I-T-E CUTTER COMPANY

ESTABLISHED 1888 PHILADELPHIA

1. Scherbius drive, 5500 h.p., Illinois Steel Company, Gary, Ind.
2. Kraemer drive, 4500 h.p., Inland Steel Co., Indiana Harbor, Ind.

Adjustable Speed Motor Drives



DIRECT CURRENT DRIVES—1. 1500 h.p. and 1800 h.p., Otis Steel Company, Cleveland, Ohio.—2. 6300 h.p., Tata Iron and Steel Company, India. —3. 800 h.p. and 1250 h.p., Trumbull Steel Company, Warren, Ohio.

Kraemer, Scherbius, or Direct Current Systems

G-E specialists in steel mill applications will gladly work with you in selecting the right system—Kraemer, Scherbius, or Direct-Current.

To meet your needs—*however exacting*—for speed control of rolling mills, we can supply that system which best suits your requirements.

7A-1

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y., SALES OFFICES IN ALL LARGE CITIES